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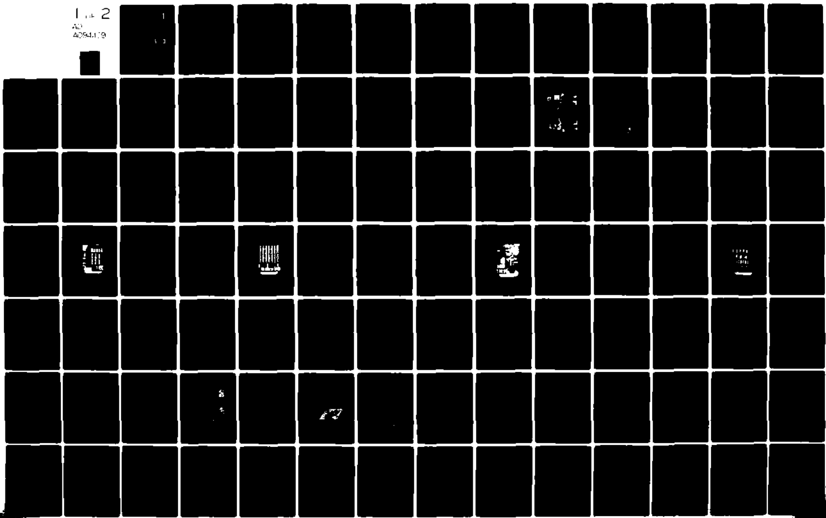

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THEATER NUCLEAR FORCE SURVIVABILITY AND SECURITY INSTRUMENTATION

Engineering Development Phase

The BDM Corporation
P.O. Box 9274
Albuquerque, New Mexico 87119

5 May 1980

Final Report for Period 1 December 1978—1 November 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the status of the engineering development phase of the TNF-S^2 Instrumentation Development effort. Evaluation of TNF-S^2 technologies, hardware, and concepts required field testing in both controlled test environments and simulated tactical environments. Free-play, force-on-force testing, and real-time casualty assessment provide the two-sided, free-flowing operational scenarios necessary to determine successfully the resolution of the majority of the TNF-S^2 issues.

PREFACE

This report was prepared by The BDM Corporation, Technology Applications Center, 1801 Randolph Rd SE, Albuquerque, New Mexico 87106 under the Defense Nuclear Agency Contract Number DNA001-78-C-0194. Lt. Col. L. A. Darda is the Contracting Officer' Representative.

This report presents the status of the Engineering Development phase for the TNF S^2 Instrumentation Development effort. This instrumentation is needed to satisfy the test analysis and evaluation requirements of force-on-force, free-play testing of the TNF using real-time casualty assessment. The instrumentation design philosophy centered around a system that is to be modular, flexible, and expandable. The instrumentation will be portable, will not require extensive field support, and in some cases will be secure from outside monitoring. Existing, off-the-shelf technology is being used to minimize development risk.

The instrumentation system consists of three basic elements. The master station performs the operations and maintenance, calibration, test control, and data quick-look tasks. The RF communications system allows for two-way communications from the master station via repeaters to the players, and will evolve into an accurate transponder position location subsystem. The player instrumentation contains a microcomputer and will be capable of totally decentralized operations. It will perform the functions of position location, weapon simulation (weapon and target sensors), player cueing, data logging, RF communications with the master station, and the computation of real-time casualty assessments.

TABLE OF CONTENTS

Table of Contents (Continued)

Table of Contents (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Concluded)

SECTION I
EXECUTIVE SUMMARY

1-1 INTRODUCTION.

1-1.1 The Requirement for TNF S^2 Instrumentation.

The Defense Nuclear Agency was directed by the Secretary of Defense in January, 1977 to implement the Theater Nuclear Force Survivability and Security (TNF S^2) program. The primary objective was to "establish a broad technological program that will allow decisions to be made on issues surrounding the survivability and security without degradation of the resultant effectiveness of the theater nuclear weapons and their delivery systems." DNA was directed to accomplish this objective by utilizing, to the maximum degree possible, systematic investigations based on realistic operational test data.

The scoping phase, which was accomplished in 1977, concluded that an instrumentation system would be required to gather the data necessary to evaluate both the current survivability and security (S^2) of the theater nuclear force (TNF) and the effectiveness of proposed improvements. Specific guidelines for the required instrumentation were given as follows:

1. Affordability -- the instrumentation development and initial procurement must not be significant in relation to the overall TNF S^2 program.
2. Cost of Operation -- the set-up time, facilities, and operations personnel costs must be minimized.
3. Maintenance and Logistics -- the instrumentation must be easily maintained (built-in test capability) and easily transported to test sites in CONUS and Europe.
4. Useful Lifetime -- the useful lifetime of the instrumentation must exceed the duration of the 5-year TNF S^2 program.

5. Flexible -- the instrumentation must operate in all types of terrain, accommodate many different player types (men, vehicles, aircraft) and weapon types, and accommodate variable player types.

Furthermore, the scoping effort identified the need for free-play, force-on-force test scenarios using real-time casualty assessment as the primary procedure for gathering the data relevant to an appropriate analytical assessment of the improvements to the S^2 posture of the TNF.

Examination of the issues supplied by USAFE, in conjunction with the Early Test Capability and Instrumentation Study efforts (both FY 1978 tasks), allowed the development of a spectrum of test scenarios with the following characteristics:

1. The number of players (to include fixed objects) is typically 30 to 50, with an occasional requirement of 100.
2. The typical playing area is several hundred meters (300 by 300 meters), with a maximum area of 2 by 2 kilometers. The convoy exercise will require a longer but narrower playing area.
3. Most scenarios have elements of close-in interactions involving participants at 3 to 10 meters.
4. The weapons systems employed are primarily portable by man or light vehicle.
5. The instrumentation must function both in day and night operations in adverse weather, and over hilly and forested terrain.

The data requirements developed for TNF S^2 testing are summarized in Table 1. This table presents the type of data, the type of analysis for which it is needed. the required/desired accuracy for such analysis, and the instrumentation system which provides the necessary information.

The Instrumentation Study effort performed in 1978 concluded that the force-on-force test instrumentation which is presently being utilized is first-generation equipment. It was designed in the 1960's prior to the existence of well-proven large-scale integrated circuitry.

TABLE 1. TNF S^2 DATA REQUIREMENTS

Player Position	Data Type Requirement/Accuracy	Instrumentation System
Deployment Analysis	15 to 25m	Position Location Candidates
Movement Analysis	5 to 10m	DME - Direct Range Measurement
		Multi-Instrumentation
Tactics Analysis	2 to 5m	TDOA - Time Difference of Arrival
Decision Criterion Analysis	2 to 5m	Radar - Range/Angle
Indirect Fire	2 to 5m	Initial - Onboard Guidance
Real-Time Casualty Assessment	2 to 5m	Accurate Position Location
		Player-to-Player Direct Ranging
		Sensor Hit Pattern Recognition
		Probability of Kill Calculation
		Player Cueing
Line-of-Sight Weapon/Target	Pairings to 2km	Laser Transmitter
Pairing	with No Anomalies	Laser Sensors
		Player Cueing
Indirect Fire Simulation		Radio Link to Players
and	3 to 5m	Flash/Bang Simulator
Hand Grenade/Explosives		Accurate Player Position
		Player Cueing

TABLE 1. TNF S^2 DATA REQUIREMENTS (CONTINUED)

Player Position	Data Type Requirement/Accuracy	Instrumentation System
Detailed Engagement Information	1 to 3m	Audio and Video Recorders
Quick-Look Data	1 to 4 Hours After Exercise	Mobile Computer
Test Initiation/Control	Pretest/Test/Posttest	O&M Capability in the Field
Data Logging	Up to 10 Hours	Onboard Bulk Storage RF Link to O&M Facility

Consequently, its operational and design characteristics reflect the capabilities and limitations of the then-available technology. Many of the previously accepted operating procedures and instrumentation technologies are now considered as severe limitations.

Today's force-on-force instrumentation has the following limitations:

1. Catastrophic Failure Modes
2. Complex Software
3. Telemetry Dependent
4. Resource Intensive
5. Limited Mobility

The equipment currently fielded, in all cases, is completely dependent upon a central computer system which tracks all of the players and scores all of the engagements. Consequently, a central computer failure or malfunction is catastrophic - the entire exercise must be halted or be reinitiated after the failure is corrected. In order that all of the required data be available at the central computer location, it is necessary that a telemetry link be operational at all times. Failure of the telemetry link is as catastrophic as a computer failure.

In support of the large central computer is an equally large and complex software package, which is costly and difficult to maintain. The human resources required to operate and maintain the computer, the software, the telemetry system, and the other instrumentation elements of the system are also quite large - and in some cases larger than the forces involved in the test.

A final consequence of the present instrumentation is that all tests must be performed wherever the equipment happens to be in place. The existing instrumentation is transportable, but by no means mobile; therefore, tests are infrequent and typically very expensive.

1-1.2 Results of the FY 1978 Instrumentation Study Effort.

With today's microprocessors and large-scale integration technologies it is now possible to develop a highly modular set of force-on force instrumentation. This instrumentation is based on the premise

that each player carries his own computer with functional subsystems supplied on an as-needed basis. The system architecture takes the form of "plug-in" modules which interface to the computer through a standard peripheral bus. This modular concept, coupled with the standard interface, allows future improvements (e.g., addition of GPS/NAVSTAR for position location) to be incorporated with no adverse impact on the other system elements.

The central computer system can now be reduced to a single easily maintained minicomputer; or, it can be eliminated entirely since each player is independent and can perform all the necessary calculations for tracking his position and scoring weapons engagements. This concept, in and of itself, eliminates the catastrophic system failure modes seen in earlier systems. It also greatly reduces the manpower requirements for operations and maintenance. The software required by each player is relatively straightforward and event-driven (external inputs).

From the above, it can be seen that position location, data acquisition, data processing, and recording can now be done on compact instrumentation located on individual players. The existing technologies have reached the stage of development where it is possible to develop, with low risk, a simple, decentralized instrumentation system which has the following features:

1. Modularity -- The addition of players does not require re-engineering or major software reconfigurations.
2. Mobility -- It will be practical to test at training sites throughout the United States and Europe.
3. Graceful Degradation -- The system fails player-by-player.
4. Reduced Support -- It requires a minimum of orchestration during set-up for each trial.
5. Directly Convertible to Training -- The use for training will be a subset of the total capability.

1-1.3 Scope of the FY 1979 Instrumentation Development effort.

The TNF $S^2$2 Instrumentation Development program is a multi-contractor effort with the BDM Corporation acting as the system integrator. The scope of the FY 1979 instrumentation development effort was to begin the development of the individual player elements and to demonstrate their capability in engineering brassboard configuration. Specific tasks which have been accomplished are:

1. Updating and revising of the Instrumentation Development Plan.
2. Hardware and software development of the overall player pack architecture, executive control system, data logging, and the audio/cueing elements.
3. Development of subsystem specifications and acceptance procedures for the weapons effects, RF, and LORAN sybsystems.
4. Technical monitoring of the DNA-selected vendors who are supplying instrumentation subsystems.
5. Integration of the prototype instrumentation.
6. Demonstrate in the BDM/TAC R&D Laboratory or at the DNA-selected vendors facilities the capability of the prototype instrumentation to meet the design specifications.

1-1.4 TNF S^2 Instrumentation - System Design Philosophy.

The TNF S^2 Instrumentation is being developed utilizing a highly modular design approach. The instrumentation will distribute the processing capability to the individual player, thereby reducing the telemetry bandwidth and the need for a large processor at the central facility.

The individual player's computer is a high performance, versatile, general-purpose process controller (a process may be software [a calculation] or hardware [a response signal]). Processes are initiated by stimuli from the player's external environment. Two examples of such stimuli are position location signals and weapon simulator laser signals. The processes which can be initiated are determined by the computer's ability to sense these external stimuli. Depending upon a player's role in a given scenario, he may or may not require access to all available external signals. Consequently, the hardware which provides access to these stimuli (e.g., radio receivers, laser sensors, etc.) is provided in the form of "plug in" modules which interface to the computer via a standard peripheral bus. Modules are provided to a player on an as-needed basis, dependent upon his function in a particular scenario.

The modular concept coupled with the standard interface allows future improvements in technology to be incorporated with no adverse impact on the remainder of the system.

Since the player-carried computer performs all the calculations for tracking position and scoring engagements, the massive central computer is reduced to either a single minicomputer or none at all. Elimination of the large central computer also eliminates catastrophic failure modes - the system degrades gracefully, player-by-player, if at all. Furthermore, small size makes the system inherently mobile. Since a great many of the support personnel requirements of a conventional system derive from operation of the central computer, those too are eliminated. Finally, the software required by each player computer is fundamentally simple - it need only perform computations involving a single player.

Thus, the concepts of modularity and distributed intelligence allow for design of a system which is highly flexible and mobile, adapts easily to changes in requirements or technology, and eliminates the serious shortcomings of existing equipment.

The use of modular instrumentation is somewhat different from standard approaches to testing. One must examine the issue at hand to determine the scenario involved (i.e., force-on-force, procedural, time-motion, etc.). One must then determine what data are required for analysis (i.e., position, real-time casualty assessment, etc.), and in some cases the necessary accuracy or precision. Finally, any unique requirements must be determined (i.e., weather monitoring, toxic gas monitors, etc.). This process provides the overall functional requirements of the instrumentation system as a whole. Using the modules available, one then very quickly assembles a system that meets those requirements.

The modularity of the instrumentation manifests itself at two levels. First, one builds a system from the three modular subsystems depicted in Figure 1. These are the master station, the player packs, and the communications system. At the second level, each of the subsystems selected is further customized by the addition of the appropriate functional hardware modules.

1-1.4.1 Player Pack.

A player is any individual or object which is instrumented with a TNF S^2 player pack. Examples are: humans, vehicles, doors, weather stations, gas sensors, television cameras, bombs, etc.

Since each player carries his own computer, he functions autonomously. A player's "signature" or functional identity is determined by the module set he carries. Thus, while a human very likely carries a weapon simulator module, a door or weather station most probably does not.

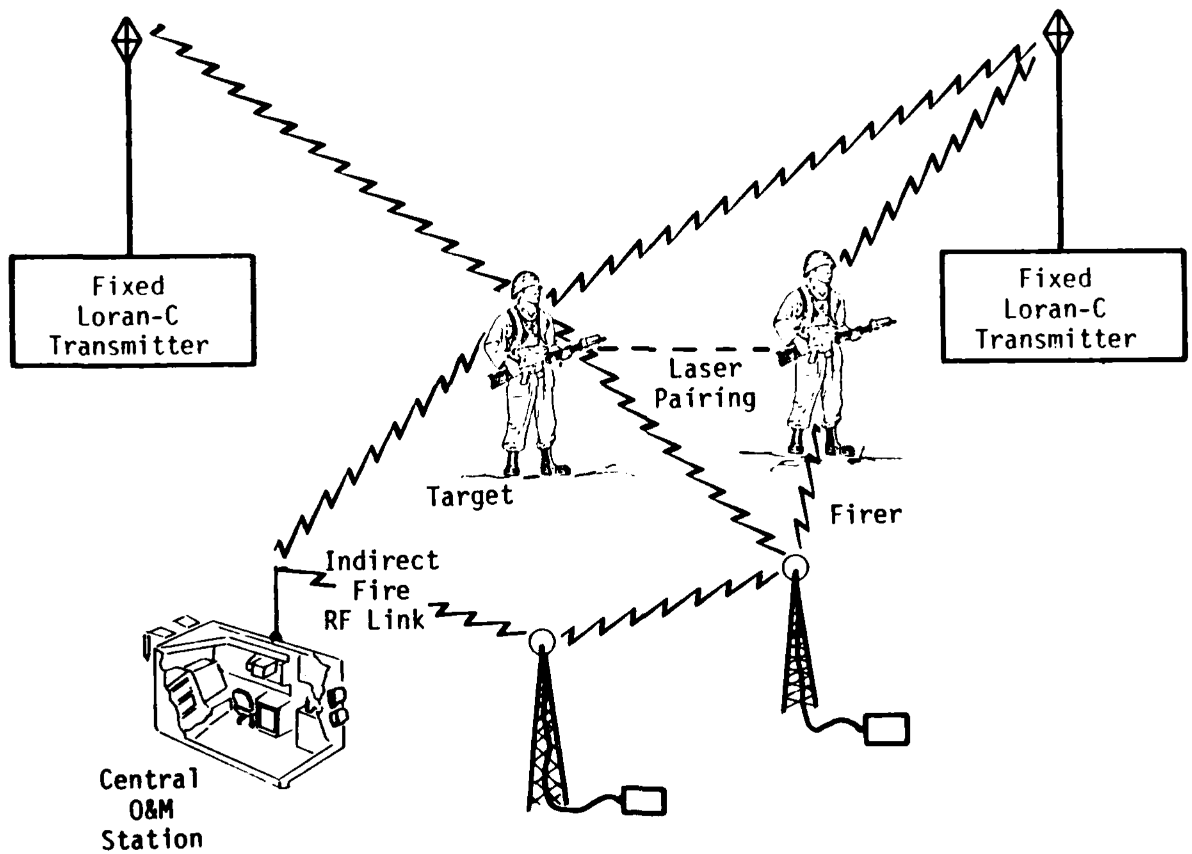

Figure 1. LORAN-C decentralized system.

The primary element of any player is of course the player pack, shown in Figure 2. Without a player pack, the individual in question does not exist as far as test control elements are concerned. His position cannot be tracked and he cannot engage or be engaged by other players.

The player pack itself consists of a fixed part called the Executive Control System (ECS), and a variable part consisting of the particular mix of functional modules (i.e., the player's unique identity). Every player pack contains the ECS, consisting of the microcomputer, the battery pack, the chassis, and the peripheral bus. Figure 3 illustrates the ruggedized packaging of the player pack.

The ECS microcomputer consists of a microprocessor, an interrupt controller, the requisite clock generation circuitry, memory and memory decoders, and peripheral bus drivers.

The peripheral bus carries the necessary control signals to all of the functional modules. All the peripheral bus connectors are identical; consequently, any module can be plugged in at any point on the bus. Use of a standard common interface greatly reduces the cost and development time of new hardware and the associated software.

Software for ECS is generically separable into two classes - control codes and computational codes. The control codes have all the features of a prioritized, interrupt-driven, multi-tasking operating system. The computational codes perform such tasks as RTCA, PL, etc.

1-1.4.2 Master Station.

The master station has been designed to serve a wide variety of functions. It is a multi-user configuration and can perform several tasks simultaneously. Even though it has this capability, it is quite small, with the computer itself occupying only two equipment racks. The Master Station, Charging Station, and the Weapons/Ammunition Stations are shown in the projected site configuration in Figure 4.

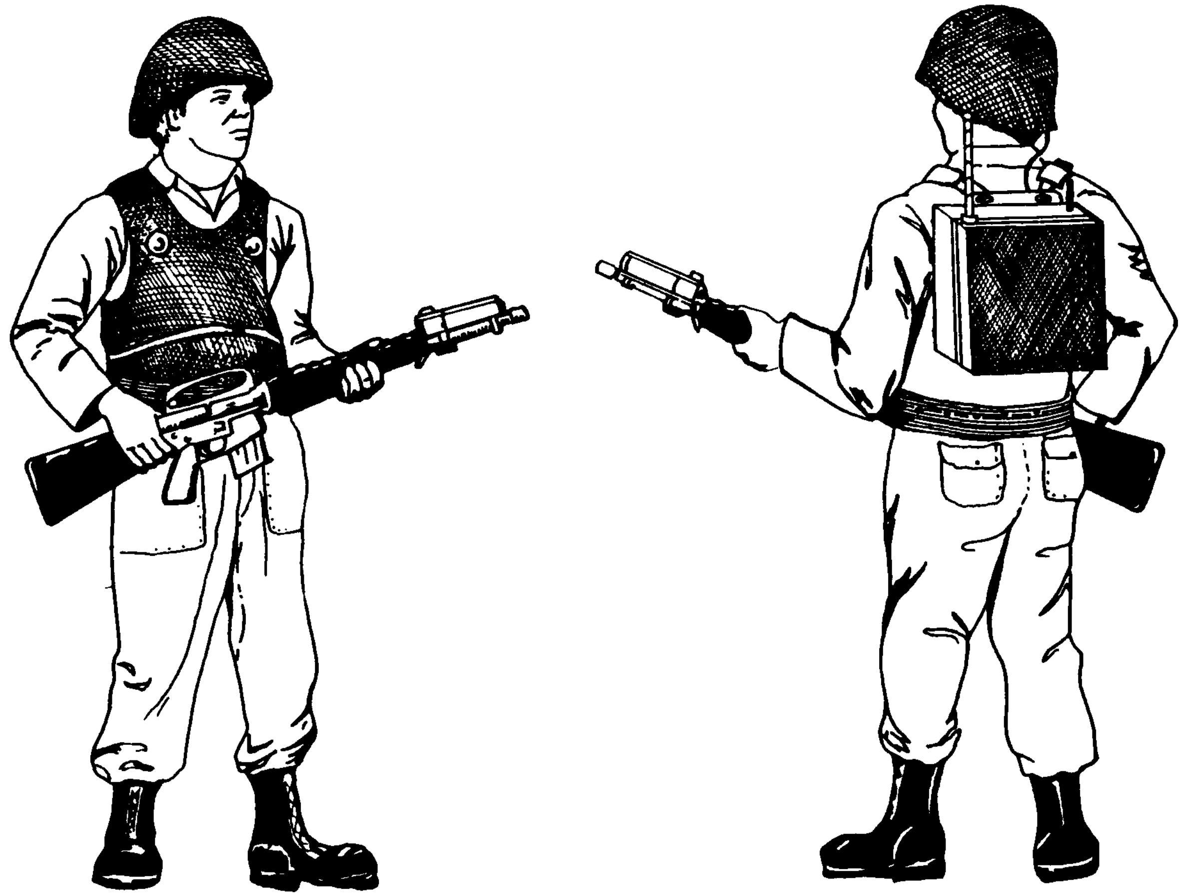

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Figure 2. Player instrumentation utilizing LORAN-C for position location.

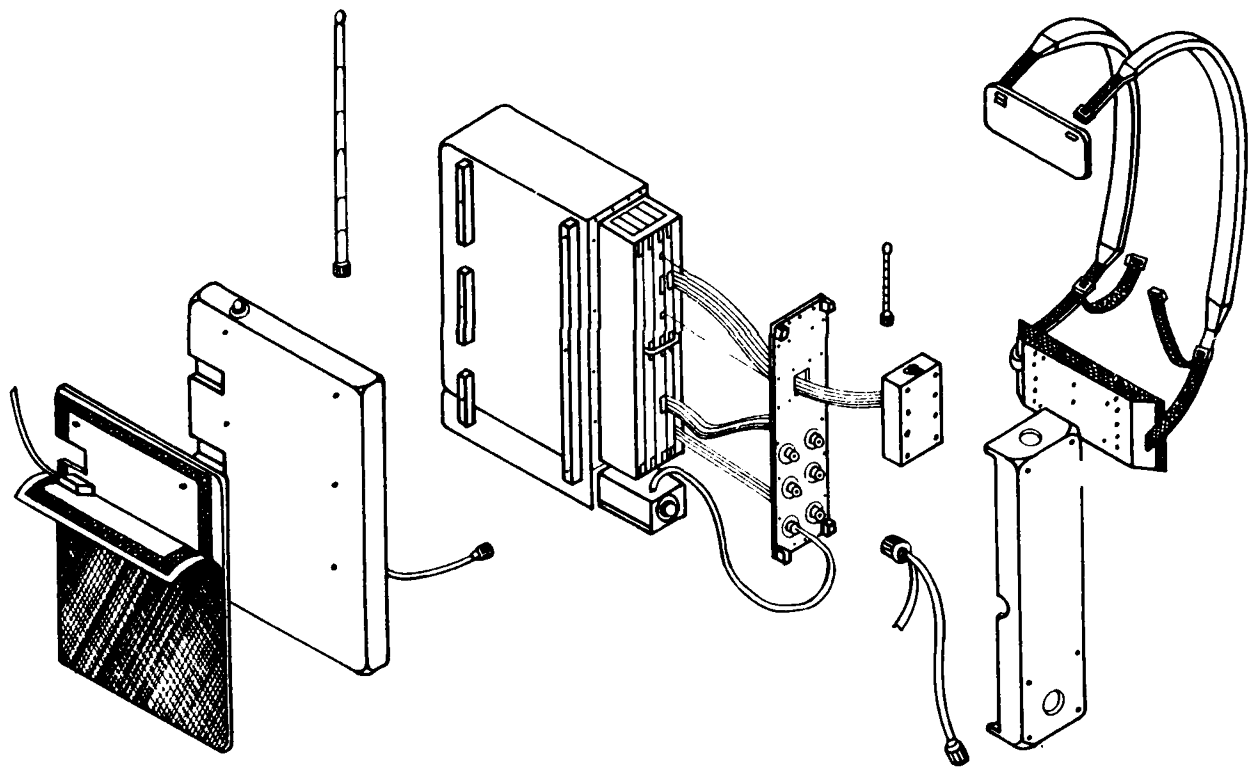

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Figure 3. TNF S^2 prototype player pack configuration.

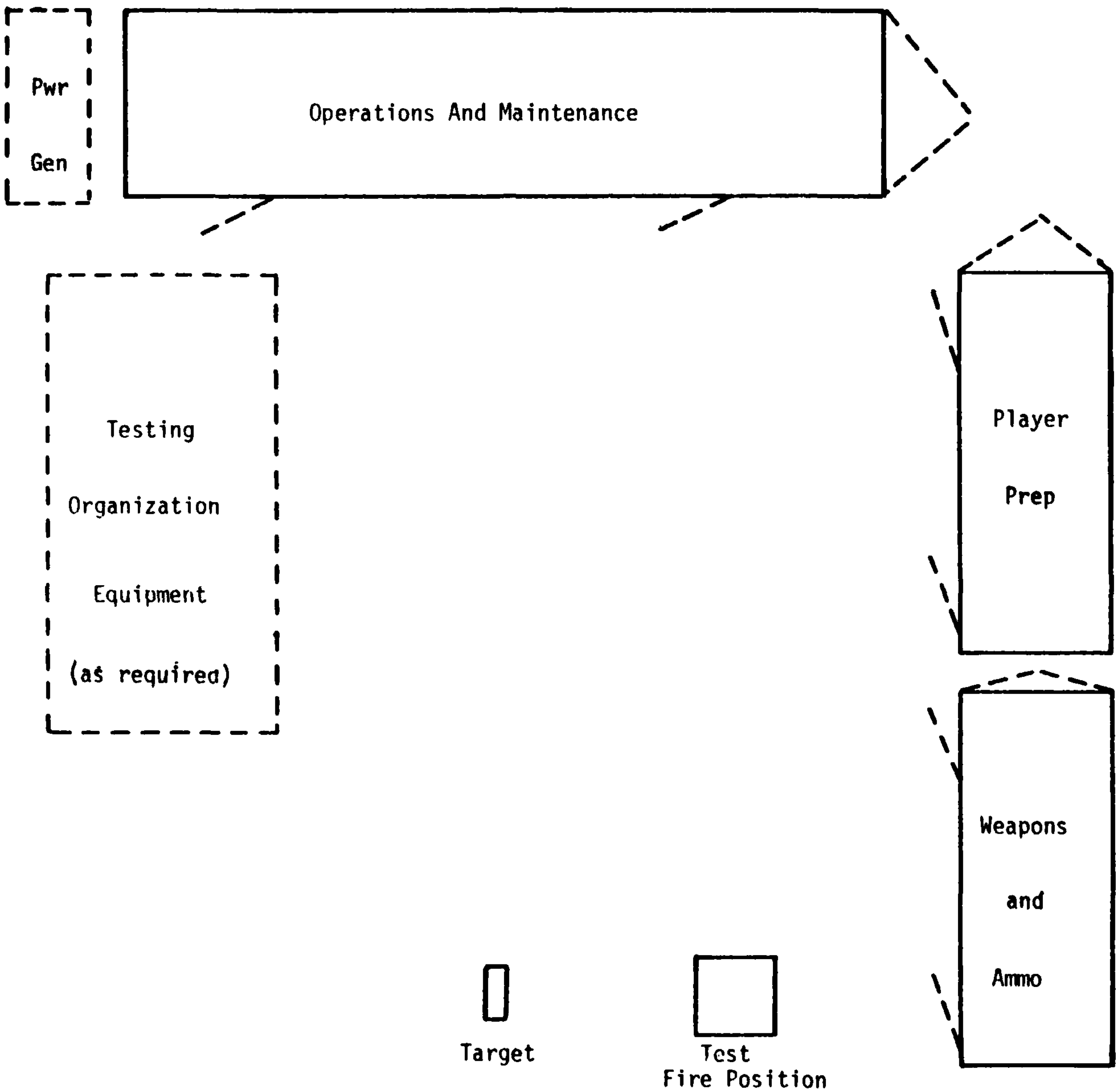

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Figure 4. Master station deployment.

The operations and maintenance function is available concurrently with all other functions. It consists primarily of calibration and functional testing of the player packs and the communications link (if used). In this role it is anticipated that sufficient software is made available so that the technician performing those duties need only type a command to "test" and wait for an indicator to signify "good/bad." This allows maintenance to be done by a less highly skilled individual than might otherwise be the case.

During pretest, the master station will supply the player packs with test and test-site specific constants, such as the coordinates of transponders, and provide for a field calibration operation. An example of a field calibration operation might be for the player to stand on a pressure switch and fire his laser weapon simulator at a specific target. He would in turn be fired upon by an emplaced laser. Both the player and the target must score a hit and indicate certain predetermined scoring data.

With the communications system in use, the master station can control test timing, start and end testing, all data traffic, transmit simulated indirect fire data, and, if required, collected stored information from the players to generate a real-time display of player activity.

In the quick-look analysis mode, the master station debriefs the player packs and validates the data structures. It further compares the player data against the test measures of effectiveness for rapid in-field test validation (at this point the test may be re-played if necessary without total re-deployment). Finally, it produces a merged test timeline tape for use in detailed test analysis.

1-1.4.3 Communications System.

The RF Communications system has been developed to provide two-way communication between the master station and the individual players. In the communications mode, the master station initiates all requests for player data and acts as a central test controller. This

feature can be deactivated at the master station with no degradation to the other system functions.

The major elements will include (1) a transmitter/receiver, logic control, and minicomputer interface at the master station; (2) a repeater/transponder with logic control at the repeater stations; logic control, and minicomputer interface at the master station; (2) a repeater/ transponder with logic control at the repeater stations; and (3) a receiver/transmitter and logic control on each player.

The RF communications system is being developed by VEGA, Inc. utilizing identical units at the master and repeater stations, with miniaturized transceivers on the players. The pulse position data encoding scheme will be identical to the laser/weapons effects subsystem and will utilize identical hardware. The configuration of a typical repeater/transponder is shown in Figure 5.

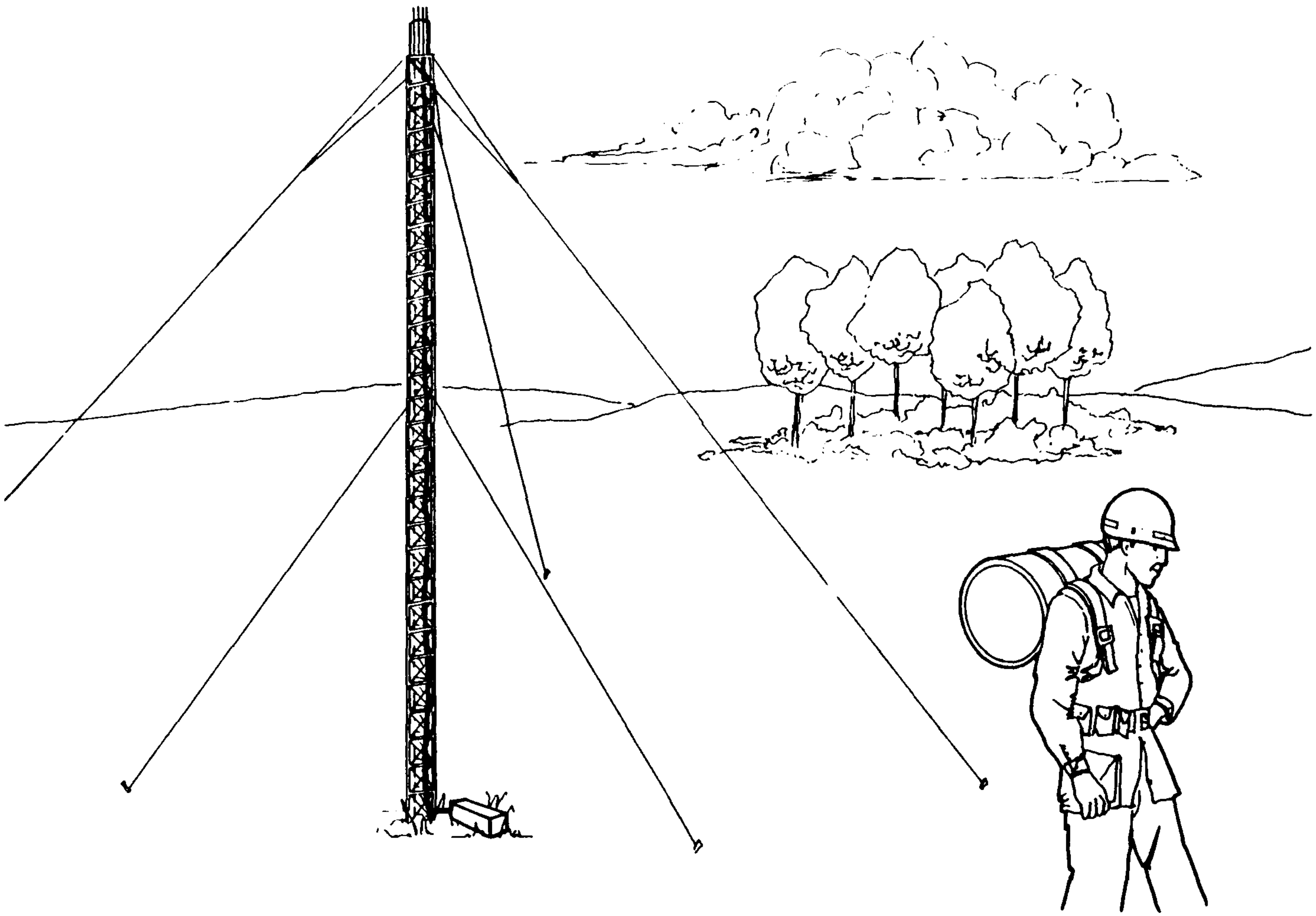

Figure 5. Repeater/transponder.

BDM/TAC-79-611-TR

1-2 INSTRUMENTATION DEVELOPMENT SYSTEM.

The instrumentation development system is a multipurpose, multiuser engineering tool to be used in the development of both hardware and software for all three of the TNF S^2 instrumentation subsystems It is configured to have the capability of serving in three modes: (1) multiuser development system for the player pack electronics, (2) quick-look and master station development, and (3) fieldable master station.

This system is critically necessary for player pack development. High-performance microcomputers such as ECS are very complex sequential and combinatorial logic networks. Their characteristics and critical paths are well-known but nontrivial. The development system provides the means to emulate the behavior of the entire system under development. Without such a development tool, the microprocessor-controlled equipment can be expected to contain many "hidden" catastrophic logic paths which become evident only after the equipment is fielded. Often these problems occur only under conditions which never arise in the engineering laboratory.

Since the master station and the development system are essentially the same equipment, many of the procedures and special test equipments produced during the player pack development phase can be transferred directly to the field operations and maintenance facility.

The commonality of the master station and the instrumentation development system also allows quick-look analysis software development to proceed in parallel with the hardware development using the same development system.

Furthermore, the instrumentation development system provides the bulk of the capability required for the depot maintenance facility addressed in Section IV.

Because the instrumentation development system is common to so many phases of the overall TNF S^2 test capability development, and because it is critically necessary for hardware and software development, it must be considered an early acquisition item.

1-3 TNF S^2 INSTRUMENTATION SUMMARY.

Each of the subsystems contains a fixed core of electronics analogous to a multi-process controller; the modules incorporated then determine what the various control processes are and when they are activated. In order to maintain flexibility, provide for rapid system-building, and allow for future growth, the core of each subsystem must meet the following objectives:

1. Capacity -- It must have the capacity to handle additional loading generated by future requirements.
2. Expandability -- It must be easily expanded to incorporate new functional modules.
3. Flexibility -- It must easily incorporate improvements to existing modules.
4. Adaptability -- It must adapt easily to new or nonstandard uses of existing modules.
5. Independence -- It must operate properly, independent of the particular mix of modules implemented.

Likewise, the modules available to each subsystem must meet an additional set of objectives:

1. Common Interface -- All must utilize a standard common interface to simplify both the bus structure and the software protocols.
2. Independence -- Proper operation of a module must not depend on the presence of another module (unless its purpose is to enhance the capabilities of that module). Use of a module should not preclude the use of other modules.

The TNF S^2 instrumentation elements and their developer are shown in Figure 6. An important feature to be noted is the use of common elements in all of the major systems. The master schedule for the development of the 15 prototype and 50 production units is shown in Figure 7. Details of the development schedule will be addressed in Section IV of this report.

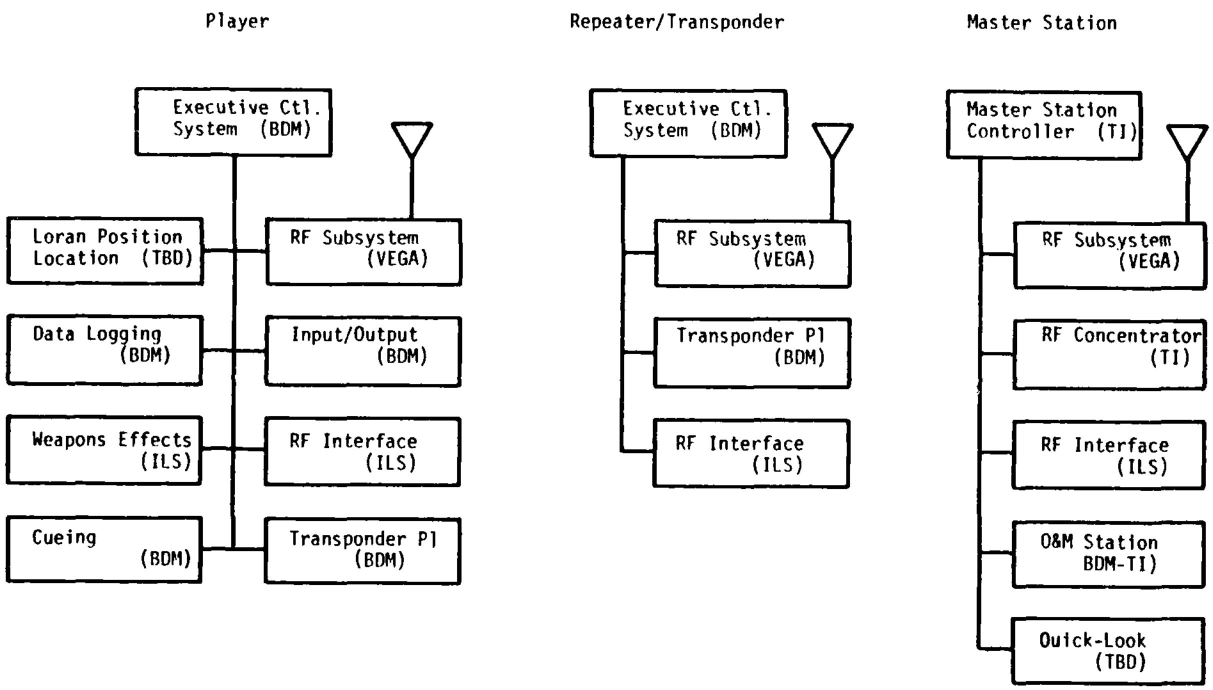

Figure 6. Instrumentation elements and developer.

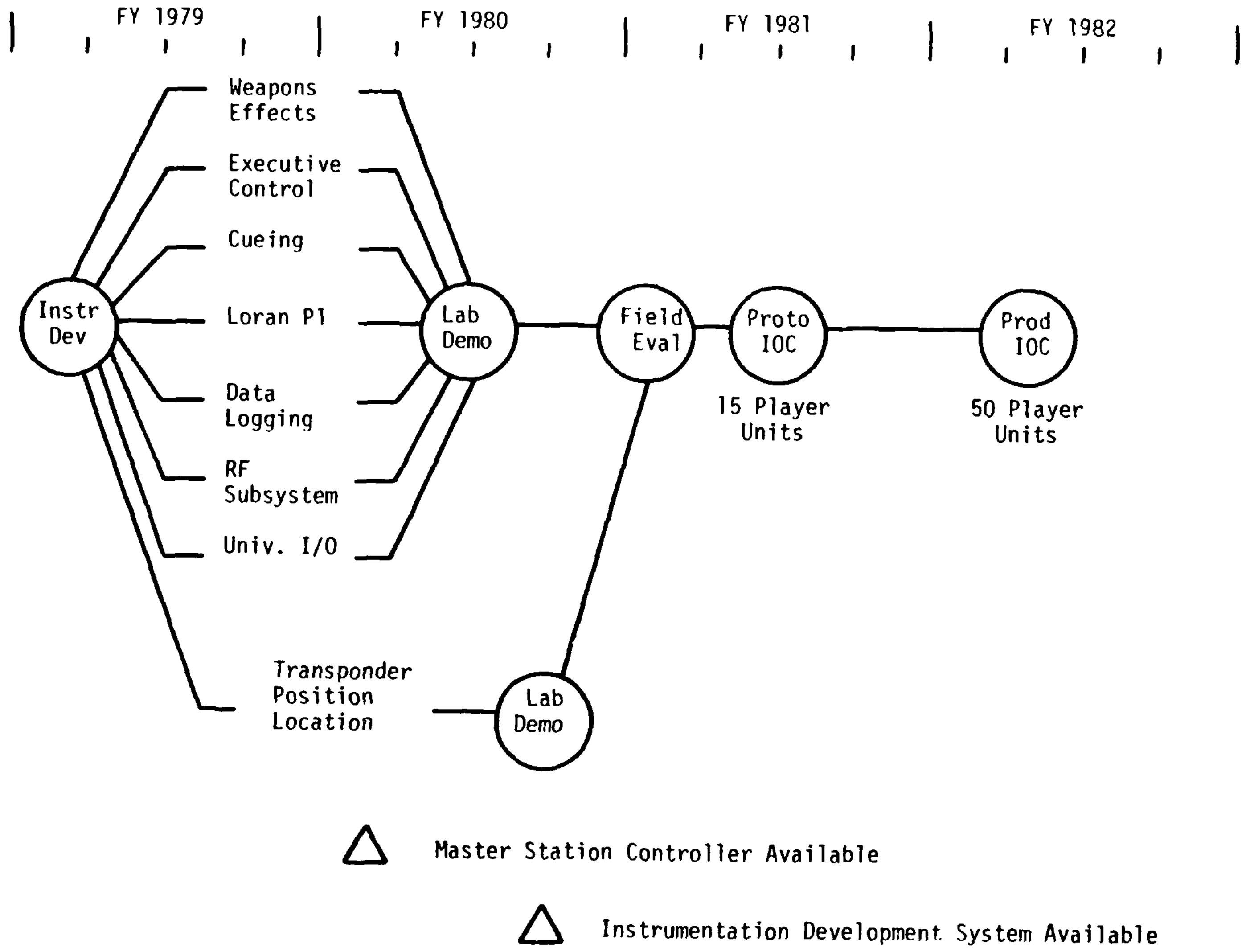

Figure 7. TNF S^2 instrumentation development master schedule.

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SECTION II
FUNCTIONAL ELEMENT DEVELOPMENT STATUS

2-1 INTRODUCTION.

2-1.1 Scope of the FY 1979 Development Effort.

The scope of the effort being reported was to develop and verify preliminary designs for the elements of the TNF S^2 instrumentation system. Because of the key role of the player pack, the greatest effort was concentrated on its development. To better utilize available expertise and reduce the total costs to the government, this has become a multi-contractor effort coordinated for DNA by BDM. Whenever subsystems or subassemblies can be provided by contractors whose primary business is supplying such assemblies those contractors have been utilized with BDM providing specifications and performing the system integration. Throughout the entire program, a low risk approach has been followed. Whenever possible, existing subsystems have been used. If no suitable subsystem exists, one has been designed, either by BDM or another contractor, using existing components and well-proven design rules.

The low risk approach has been highly advantageous in terms of both cost and schedule. The Phase I player pack brassboard stage is nearly complete. Design of the RF repeaters is nearly complete and the Master Station design is well underway.

VEGA Precision Laboratories is under contract to DNA and will provide RF transceivers. International Laser Systems is developing new solutions to old problems in the area of weapon simulators. BDM has worked closely with both contractors to assure that the operational goals are both realistic and achievable using the low risk design rule.

2-1.2 Player Pack Development.

As stated earlier, the player pack is the key element of the TNF S^2 instrumentation system. Consequently, the bulk of the total

design effort has been dedicated to the player pack. A phased approach -- brassboard, prototype, production -- has been adopted to ensure that the operational characteristics of the final production model are as close to desirable as possible. In some cases (notably the microcomputer) operational shortcomings were recognized early and a Phase II design is already in progress.

Many of the criteria for the player pack are nearly mutually exclusive: High speed real-time operation and low power consumption; Modularly flexible and small size; operation over several hours and low weight (batteries). To achieve these contradictory goals some highly innovative techniques have been used. Power is cycled to low duty cycle components to reduce total power consumption. CMOS logic is used where-ever high speed is not critical. Finally, a great deal of effort has been expended in properly partitioning the player pack circuitry to reduce the size of connectors and still provide adequate flexibility for future growth.

Software development has lagged due to procurement difficulties with the GFE Instrumentation Development System. Nonetheless, it is anticipated that three brassboard player packs will begin field testing in late April 1980.

The following paragraphs provide a detailed account of the current status of each of the component elements of the player pack.

2-2 Executive Control System Microcomputer

The requirement to incorporate a microcomputer in the player pack stems from the real-time nature of the TNF S^2 scenario. As fire activity reaches a maximum during such tests, the ability of the instrumentation system to respond to events is taxed. It is for this reason that large central site computing facilities have proven ineffective in handling real-time data at a rate to ensure optimum realism. The microcomputer on the other hand provides immediate response on the player to events as they occur. Its job is to coordinate the activity of the instrumentation within the player pack in order to log real-time data, compute the player's status (hit/wound/kill), and provide an intelligent means of communicating back to the central site via the RF network.

Historically, implementations of microcomputers have suffered from a lack of support from their vendors. This has been quite evident in the last five years and is largely due to the growing family of microprocessors. As microprocessors have become the heart of many new instrumentation designs, manufacturers have continually up-graded their parts and designed new and in some cases better parts. This put the average lifetime of a design at about two years and did not enable the manufacturers to develop full support, both software and hardware, for their products. To circumvent this pitfall, a microprocessor from Texas Instruments has been selected for the TNF S^2 application. For a couple of years this device has been the only 16-bit microprocessor to have minicomputer support from the factory. What this really means to TNF S^2 is that field service and direct software compatability with the mini will ensure that the microcomputer used in the player pack is not going to be outdated for quite some time.

2-2.1 Central Processing Unit

There are several components involved in the design of a microcomputer. Each of the major components contributes unique capabilities to the system and the design effort of the microcomputer has

been made to optimize this board for the TNF S^2 application at the same time providing for some expansion. As a result, modularity and flexibility have been key design considerations.

Figure 8 is the block diagram of the first brassboard microcomputer which was designed and built this year. The major components have been depicted as blocks and provide the following capabilities on the microcomputer board:

(a) DIRECTLY ADDRESSES UP TO 64K BYTES OF MEMORY

(b) 15 PRIORITIZED INTERRUPTS

(c) BOOTSTRAP READ ONLY MEMORY (1K BYTE)

(d) REAL TIME CLOCK

(e) SERIAL COMMUNICATIONS REGISTER UNIT

(f) HARDWARE ARITHMETIC PROCESSING

As mentioned before, the Phase I (brassboard) microcomputer concept was designed and checked this year. The following design rules were incorporated for all the player pack cards: (1) keep the design simple -- eliminate parts and complex schemes wherever possible, (2) keep power consumption at a minimum -- use CMOS parts and low power devices throughout, (3) make the design with testability in mind, (4) consolidate circuitry as much as possible to improve reliability and decrease stocking requirements, and (5) use worst case vendor specifications on parts to minimize design risk.

2-2.2 Programmable Systems Interface

While the Phase I microcomputer card was being tested, an upgraded design concept was adopted for the board. As with most engineering projects, a "lessons learned" stage provided insight for a Phase II brassboard which will prove to be more flexible than the original microcomputer. Also, in an effort to reduce the overall size and weight of the player pack, 16K bytes of Random Access Memory will be incorporated onto the microcomputer card (see Figure 9). Additionally, it was decided that the 500mA current regulator for the microprocessor would

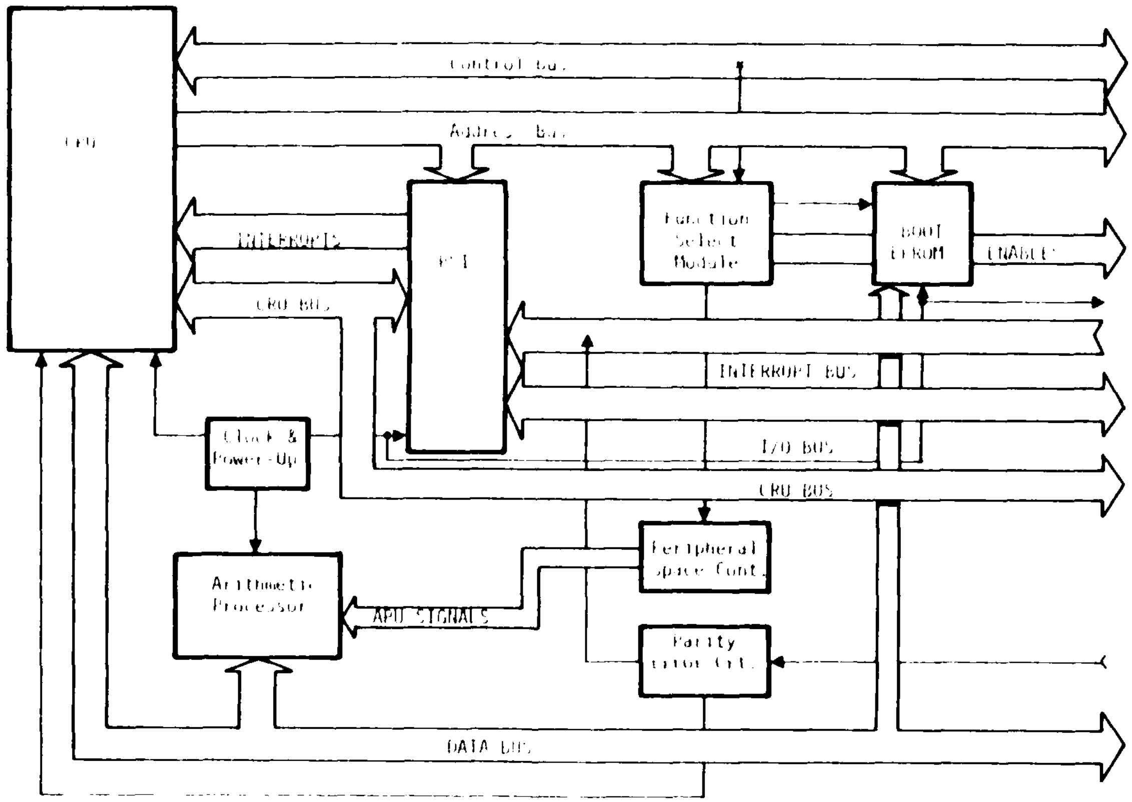

Figure 8. ESC microcomputer board block diagram, phase I.

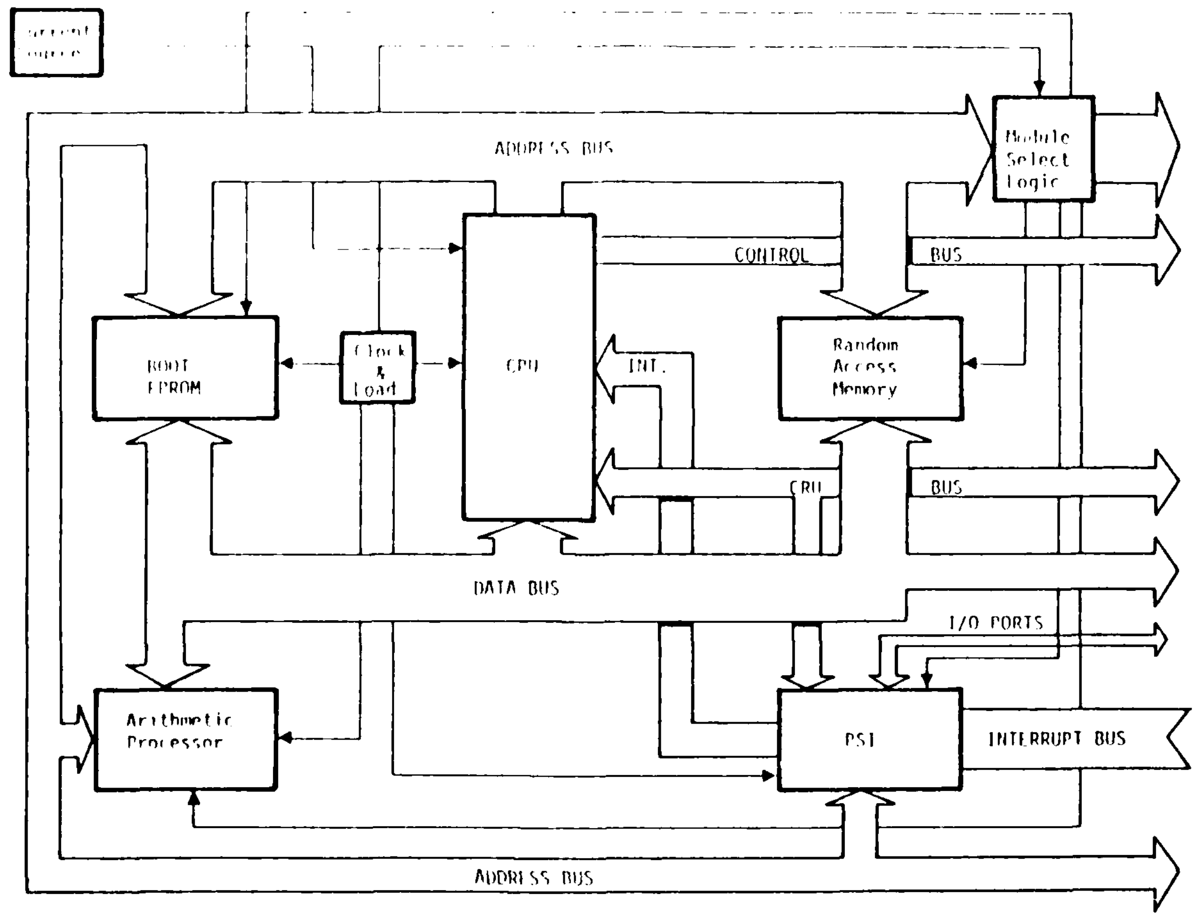

Figure 9. ESC microcomputer board block diagram, phase II.

reside on this board since no other components require this supply. These additions to the microcomputer board will result in the use of a "multi-wire" printed circuit board fabrication technique which is designed to condense the physical size of electronic subassemblies.

The Phase II microcomputer is in the design stage presently. Once reviewed, a wire-wrap version will be assembled and debugged. After it has been functionally checked out, temperature tests will begin. This will involve operating the microcomputer and exercising on-board circuitry from 0 to 70° Centigrade. When this has been completed, the prototype multi-wire boards will be purchased. All other system components (Data Logger, Input/Output, and Communications Interface Unit boards) will then begin being tested for functionality and compatability with the microcomputer board.

2-3 Memory Subsystem

For convenience of discussion, the memory subsystem will be divided into two parts: the storage memory subsystem and main memory subsystem. The storage memory subsystem provides for the permanent storage of all software that is used by the player pack while in the normal running mode of operation. When the system is turned on, the software in the storage memory subsystem is copied to the main memory subsystem and then executed. The storage memory subsystem is not accessed again unless a fault is detected or the power is turned off and then on again.

2-3.1 Storage Memory Subsystem

The storage system memory provides for the retention of the player pack software when there is no power applied. This board holds the basic software the player pack will use during a test. This includes the software for the system, tasks, device service routines, and tables. The basic component of this memory is EPROM (Electrically Programmable Read Only Memory). This device can be electrically programmed to contain any software and it remains intact with interruption of power. The software can only be erased by exposure to an intense ultra-violet light of a specific wavelength. Accidental erasure is virtually impossible while inside the player pack. Once erased, these devices may be reprogrammed.

By transferring the software to the main memory subsystem, Random Access Memory, the software can dynamically change during the test. This relaxes the restraints on software generation. This is important because software generation is a significant part of development cost. The EPROMs are not used except for a few seconds at initial power-up. To conserve power, the ECS can turn off the power to the EPROMs. This reduces both the required amount of energy needed and battery weight. The functional block diagram of the storage memory subsystem is shown in Figure 10.

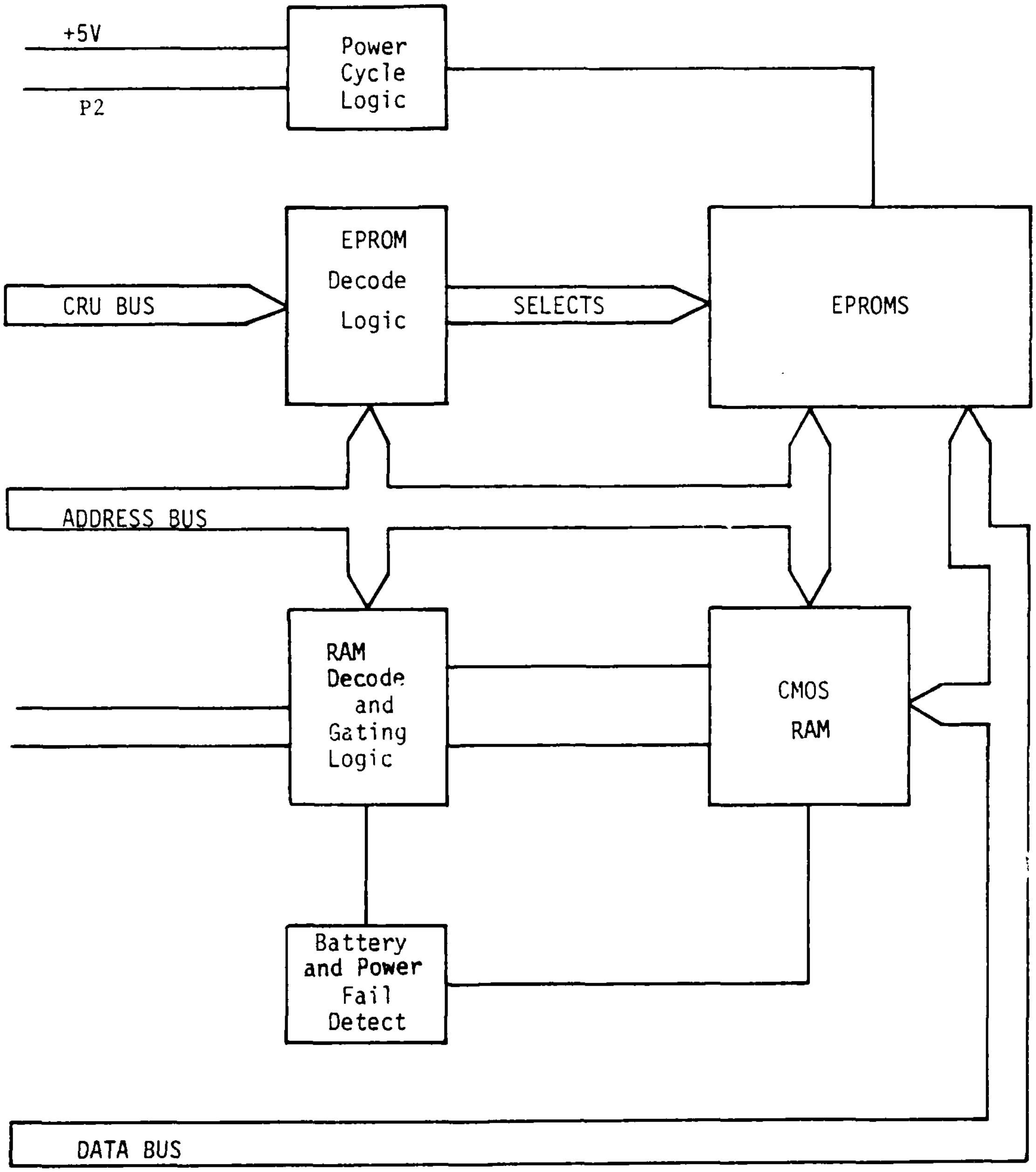

Figure 10. Storage memory system functional block diagram.

Because the EPROMs are used for so short a period and the transfer rate is unimportant, they have been configured in such a manner as to reduce addressing space. The EPROMs are configured as four sets of two EPROMs each. The four sets are multiplexed using the Communications Register Unit (CRU) bus to control the multiplexing. The prototype EPROM board is shown in Figure 11. The operation of the EPROMs proceeds as follows:

(1) The EPROM power is turned on.

(2) One set of EPROMs is selected, via the CRU bus, to respond.

(3) The software from that EPROM set is copied into the main memory subsystem.

(4) The next set of EPROMs is selected to respond.

(5) The software is copied into the main memory subsystem and so on until all of the EPROM sets have been copied.

(6) The power to the EPROMs is turned off.

Some RAM (Random Access Memory) has been added to the board. Each RAM may be written to, read from, and rewritten to independently and in any order. The RAM is present to allow easy field modification, either temporary or permanent. RAM, however, is volatile. Consequently, when power is interrupted the data stored within it is lost. To prevent this, a small battery on the board keeps power applied to the RAM when the rest of the playerpack is off. The RAM is fabricated from CMOS (Complimentary Metal Oxide Semiconductor) technology because of its extremely low power requirements. External gating prevents writing to the bulk of the RAM unless special conditions are met to prevent accidental loss of data. The area that can be written to is used to hold player status and ID information. This RAM is accessed like the EPROMs, but the EPROMs must be turned off to do so.

2-3.2 <u>Main Memory Subsystem</u>

The main memory subsystem contains the volatile Read/Write RAM memory. RAM is a mandatory part of present day microprocessor systems.

In the most fundamental processor application RAM is used only for temporary information storage. For TNF S^2 this memory is used for

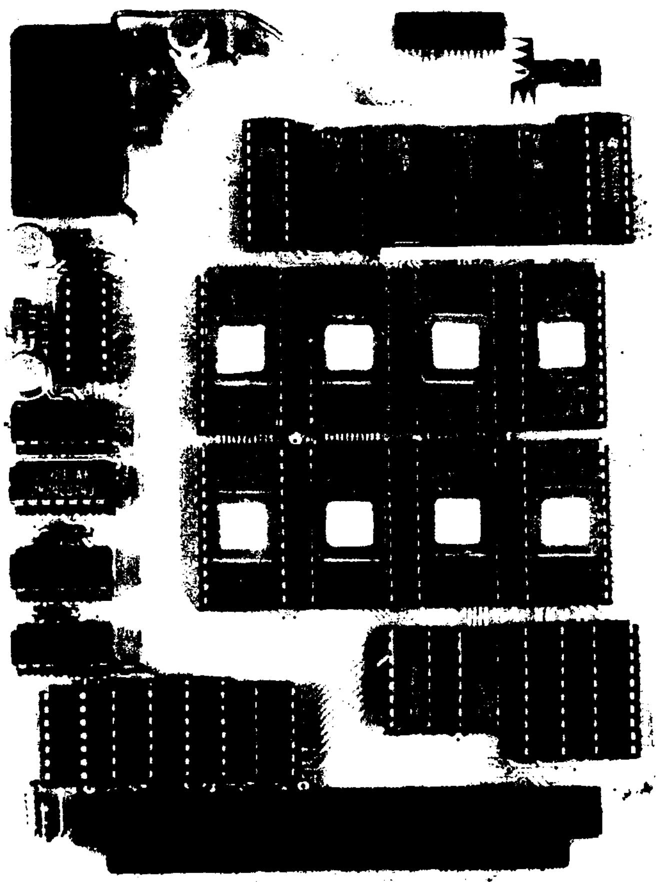

Figure 11. EPROM board.

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all active software, instructions, and data. More specifically, the RAM will hold the operating system, tasks, device service routine, tables, and temporary buffers. An estimate of 8k words (8192 x 16 bits) is required for TNF S^2. A 4k bit (4096 x 1) static RAM is the basic memory device. Sixteen of these devices are used in parallel to produce a word. Two sets of these blocks are used to get the total memory required. A 5-1/2 x 6-3/4 inch board is used for RAM memory. The 4k bit RAM devices selected have several technological advantages over other RAMs. They have very low power consumption with adequate speed and density. The RAM devices also have a high output drive capability. In order to insure reliable performance, parity is included in the design. Parity allows the processor to detect single bit errors in stored data.

Figure 12 is a functional block diagram of the RAM board. Each bank of RAM is composed of 17 RAM devices, 16 for data and one for parity. The decode and control circuit uses the upper address lines and memory control signals to determine selects to the RAMs and proper timing. The parity circuit generates a parity bit for each write that is stored in RAM. The circuit checks the parity stored with that generated when the word is read; if a mismatch occurs, the parity error becomes active. Figure 13 shows the prototype RAM PCB.

Due to the sensitivity of the cassette tape drive unit to shock and vibration, a feasibility study was initiated to investigate other alternatives to mass storage devices, primarily magnetic bubbles and bulk (hybrid) CMOS RAM, that were not available for evaluation during the design phase of the data logger subsystem module.

Now that magnetic bubbles are available for evaluation, the decision was made to procure an evaluation kit. A more dense and reliable storage medium such as magnetic bubbles could potentially replace both the cassette tape version of the DLS and the software storage EPROM board.

2-3.3 Bubble Memory Devices

Bubble memories are approaching the stage where they are convenient to use. These devices have several characteristics which

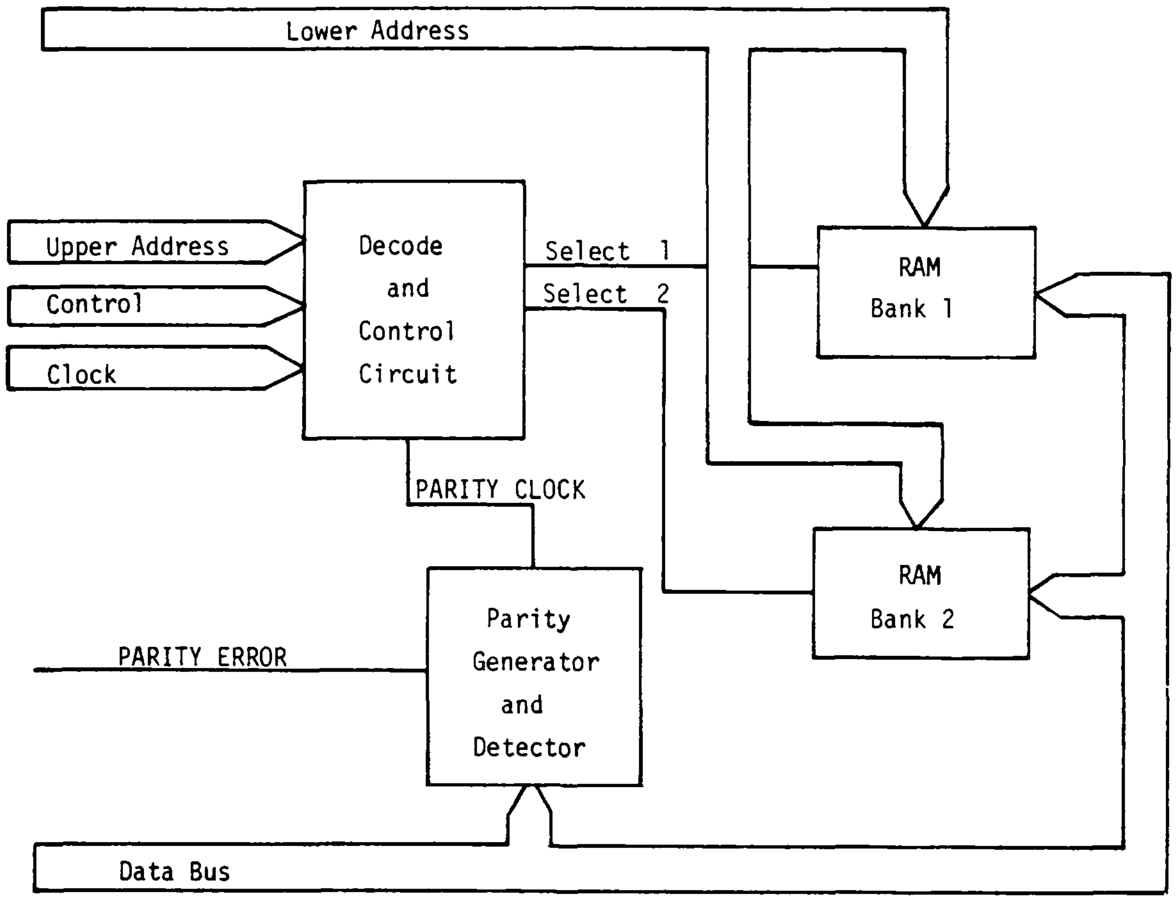

Figure 12. RAM board functional block diagram.

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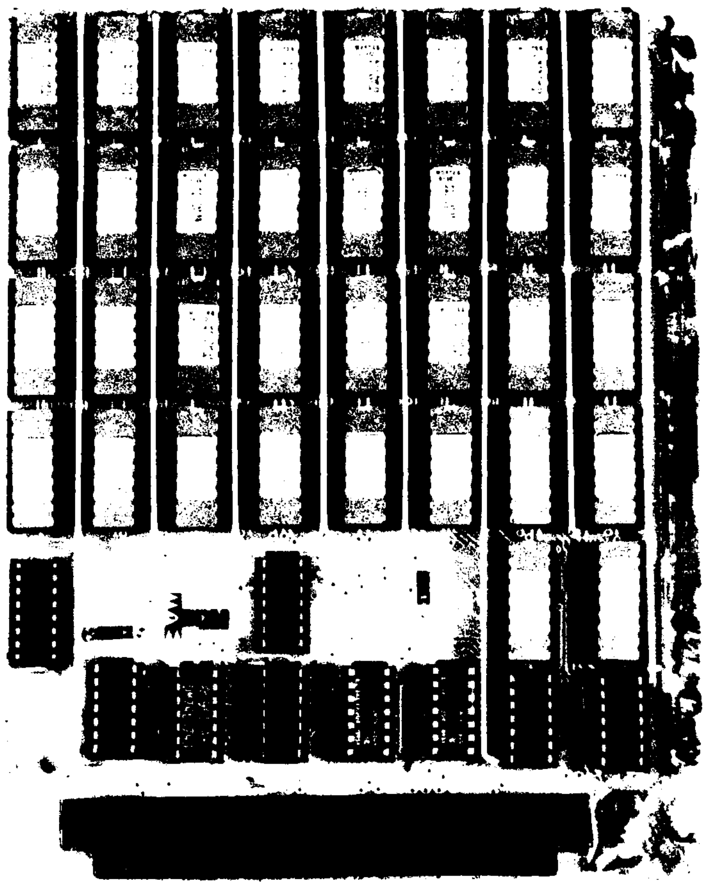

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Figure 13. RAM board.

make them attractive as a high density data storage medium. First, there are no moving parts so reliability will be high. A single bubble device has sufficient storage capacity for TNF S2 and expansion is relatively easy. The package is suitable for mounting on a single PC board, the form factor for the player pack. The device is nonvolatile but is easily written too. When not in use, the bubble memory itself dissipates no power. A bubble memory device will replace the present data logging subsystem using the minicassette at half the volume, and also replace the EPROM board (Storage Memory Subsystem). For the prototyping stage system, the data logging subsystem and the EPROM board will be used.

2-4 Data Logging Subsystem

The purpose of the Data Logging Subsystem is to provide a non-volatile data storage capability on the player pack. Since the storage requirement for the player pack exceeds the addressing capability of the ECS microcomputer, the data logging subsystem will be implemented as a separate mass storage system. The data to be stored can be classified as routine tracking records and event initiated records.

Routine tracking data provides a position/status vs. time player history. These records are written at regular intervals and allow the analyst to produce a chronological map of player position and status during a test. Event initiated data does not occur at regular intervals, but only as circumstances dictate. These records must contain all the analytically necessary information concerning such events as weapon firing, being fired upon, etc. To the greatest extent possible, these records will contain the information in immediately useable form to facilitate the Quick-Look process.

After a test, the data stored in the data logging subsystem will be unloaded. This will be done either through the RF link or through an input/output port. In the player pack application the data logging subsystem could also be used to store volatile software and constants during the time it is necessary to turn off the power to the player pack. The data logging subsystem can be divided into three functionally distinct blocks. Each block will be described below. Refer to Figure 14, block diagram of the data logging subsystem.

2-4.1 Data Storage Medium

The storage medium, for the brassboard prototype units, is implemented with a miniature cassette tape recorder using endless loop-type tape cassettes with a capability of storing up to 64K bytes (8 bits/1 byte) of data. The tape recorder will store and retrieve data presented to it under command of the data storage controller. See Figure 15 for the prototype cassette data logger unit.

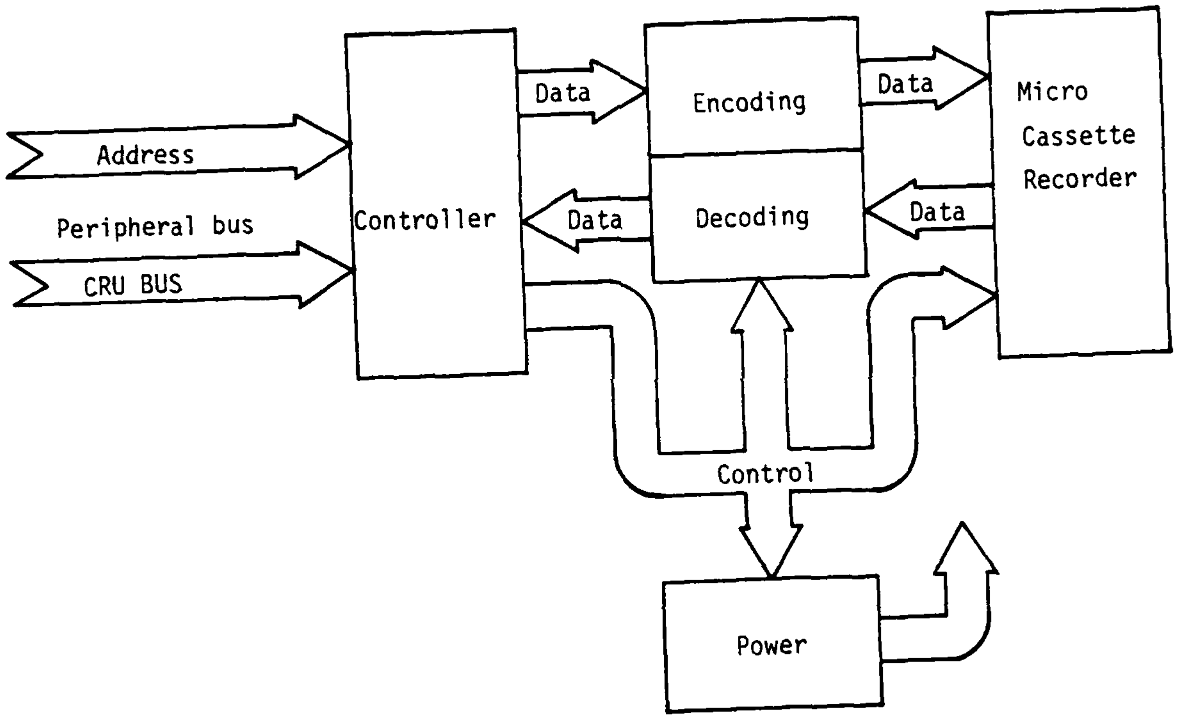

Figure 14. Block diagram of data logging subsystem.

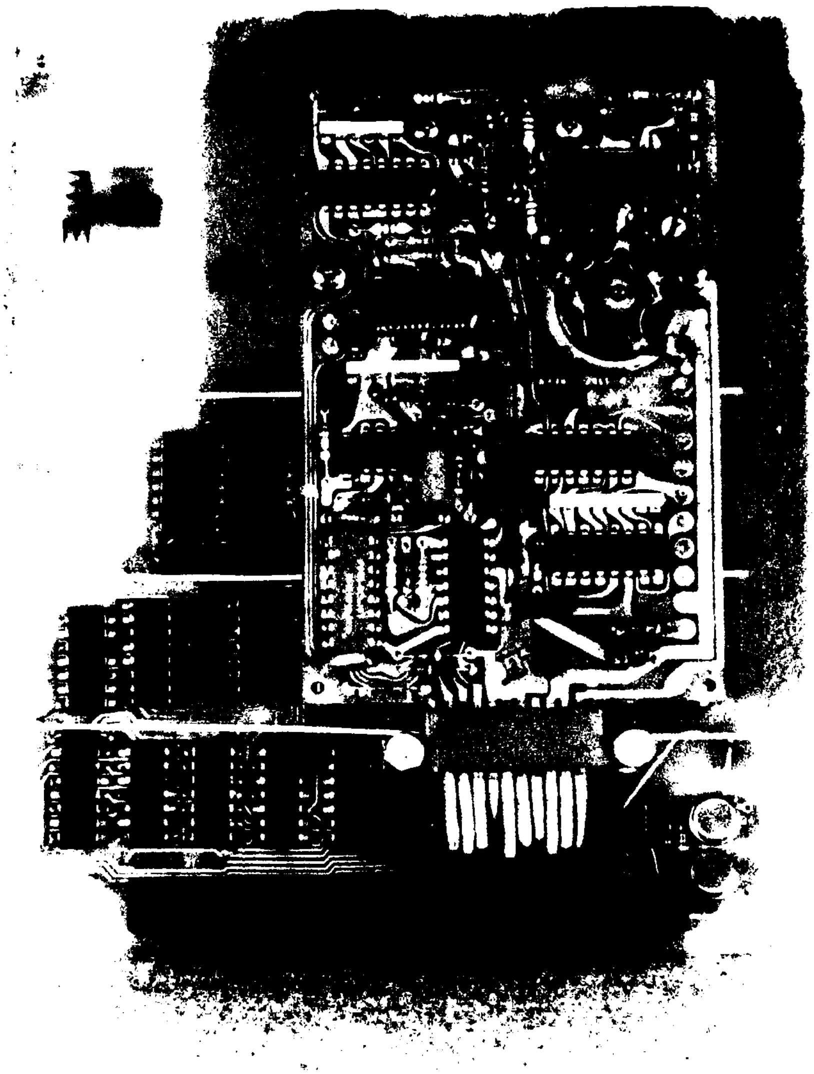

Figure 15. Data logger unit.

2-4.2 Data Storage Controller

This portion of the data logging subsystem interfaces to the ECS peripheral bus. The data storage controller supplies the necessary control signals, performing timing, data serialization, and deserialization functions to store and retrieve data to and from the storage medium.

Functionally, ECS will supply the data storage controller with data to be stored in the data logging subsystem through the Communications Register Unit. ECS will address the data storage controller and program it with command and control information to be used when storing data onto tape. ECS will also turn the power on and off to the controller as to avoid unnecessary power drain when not in use.

This process is reversed under the control of ECS for unloading the stored data. ECS will access the data storage controller and read its outputs to sense the status of the device. Likewise, the retrieved information will be read by ECS through the peripheral bus.

2-4.3 Data Storage Buffer

For a tape storage system to be efficient, it must utilize a buffer so that data can be stored on tape in blocks. If data is recorded on tape byte-by-byte, too much tape will be wasted due to start and stop distances. Therefore, part of ECS memory (1k bytes) is used as buffer memory. When full, under software control, ECS will present the data logging subsystem with data from the memory buffer. This process is reversed for unloading the data stored.

2-5 Universal I/O Subsystem

The purpose of the Universal I/O modules is to enhance the flexibility of the player pack by providing two-way electrical communication with the outside world. The player pack could contain one or more Universal I/O modules, each module containing the required hardware to enable ECS to communicate with external devices.

On a human player, the Universal I/O module will be used to control cueing devices, monitor posture, supply the interface to the Loran-C position location subsystem, and in the future could be used to monitor blood pressure, heart rate, and other physiological variables as needed.

On vehicles, the Universal I/O module will be used to control flash/bang/smoke cueing devices. The module will also be able to monitor, sense, and control other variables specific to vehicles, such as deactivating the engine, sense speed, and rpm.

As a controller for test-specific equipment, the player pack could be used to activate TV cameras, sense intrusion detectors, and monitor weather stations using the Universal I/O module.

The player pack will also have the capability to load/modify/unload software from external sources through the Universal I/O module. The Universal I/O module is a software-controlled input/output port. The module will interface with almost anything such as RS-232, IEEE-488, other logic devices, and data buses, all just by changing the software.

For the brassboard and prototype units, all the Universal I/O module functions will be described in the following paragraphs.

The Universal I/O module provides 16 input lines and 16 output lines. Each input and output line may be addressed by ECS as an independent digital signal (value) or in groups of up to 16 lines. A block diagram of the Universal I/O Module can be seen in Figure 16, and the prototype PCB is shown in Figure 17.

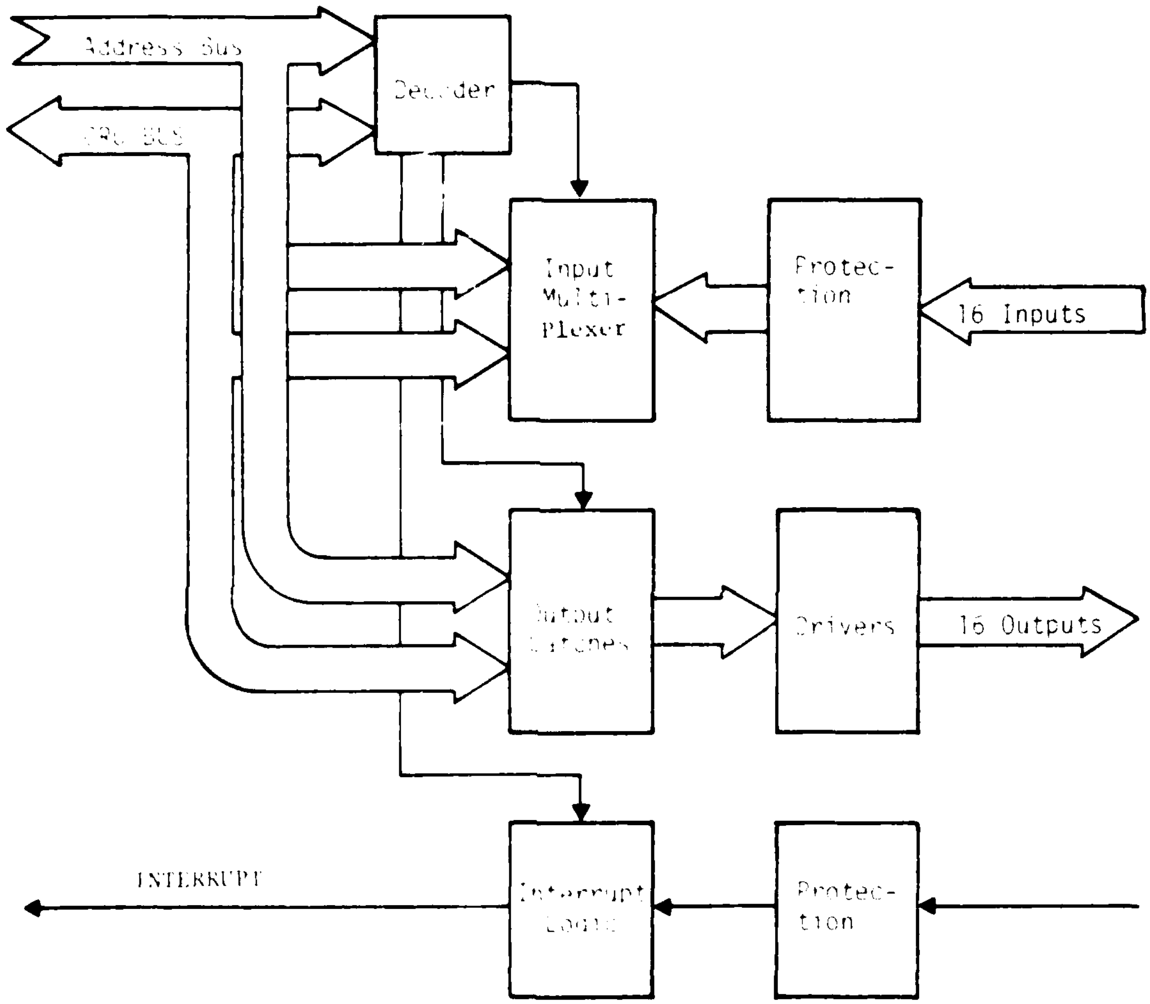

Figure 16. Block Diagram of Universal I/O.

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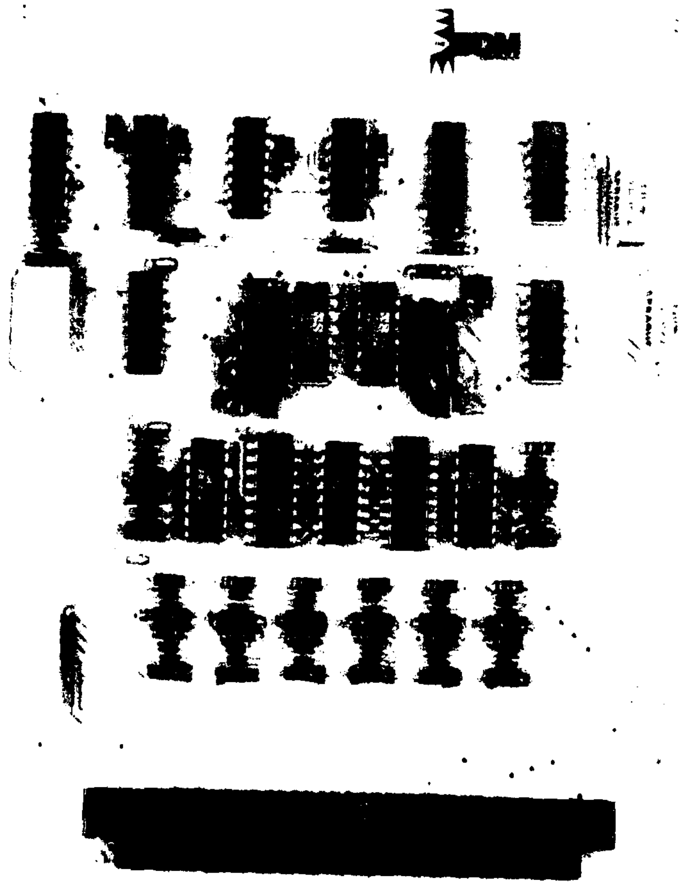

Figure 17. Universal I/O board.

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ECS communicates with the Universal I/O module through the Communications Register Unit bus and the address bus.

The Universal I/O modules can be plugged in to any of the six peripheral bus connectors, since all the peripheral bus connectors are identical. The peripheral bus carries all the necessary control signals to the Universal I/O modules. Each Universal I/O module decodes the peripheral bus and responds when it is issued a module select signal.

Each module, during initialization, generates a special interrupt which tells the CPU that the module is present in the system and what interrupt is associated with the module. This is useful since each module can be located in any of the six peripheral bus connectors. The interrupt logic provides latched interrupt request signal to the ECS board.

Each output has an open drain type driving Vertical Metal-Oxide Semiconductor Field Effect Transistor (VMOS FET). The outputs will interface to any system requiring a 5-30V swing and to almost any load requiring several hundred milliamps of current. Furthermore, the lack of failure from secondary breakdown means that the outputs can drive inductive loads such as relays.

All digital inputs to the I/O module accept Transistor-Transistor Logic (TTL) level signals and are protected against any input voltages above +5 Volts or below ground potential (zero Volts). The inputs could therefore interface with standard 24 Volt logic level systems. Further, the inputs are protected from input transients of up to two kilovolts for one second.

2-6 Battery Pack

This task entails the selection and evaluation of the optimal power source for the TNF S^2 player pack. Associated with the battery implementation is the power conditioning of the cell array voltage to provide regulated voltage and current sources.

One of the prime objectives is to assure that the player pack power source is the smallest and lightest available using high technology cells. In conjunction with the prime objective, a high efficiency regulation design is required. Also, a simple design and configuration is necessary to minimize the cost of battery re-charge/ replacement.

2-6.1 Design Evaluation

Prior to the actual design of the player pack power source, a market survey of available battery types and their characteristics was made. To accomplish this, power consumption estimates were obtained from the members of the electronic design staff. This rendered a voltage, current, and power requirement for each circuit board. Several battery manufacturers were then contacted to acquire the most current available literature on cells. Table 2 indicates a compilation of data on secondary (re-chargeable) cells.

TABLE 2. CYCLE LIFE AND POWER DENSITY FOR SECONDARY CELLS

	NI-CAD	SILVER-CAD	NI-ZINC	SILVER-ZINC
CYCLE LIFE	300 min.	150 min.	150 min.	25 min.
W-hrs/lb.	14 typ.	28 typ.	23 typ.	45 typ.
W-hrs/in^3	1.5 typ.	2.1 typ.	1.4 typ.	2.8 typ.

The silver-zinc cell was chosen as the candidate from the secondary cells because of its high energy density. Taking a look at primary cells (non-rechargeable), the most dense are the lithium cells. Although they would have to be thrown away after each test, a 50% savings in battery weight could be expected if lithiums were used. A cost trade-off between the lithium cells and the silver-zinc cells revealed that 17 cycles was the break-even point. In other words, if the silver-zinc cells could be recharged and used for more than 17 tests, they would be the more cost-effective battery for the TNF S^2 player pack. At this point in the battery survey, it was noted that a particular silver-zinc cell from Yardney Electric (LR-6) had been developed for military applications and packaging advances had increased the density of this cell to about 60 w-hrs/lb. A configuration suitable for the manpack using these cells would yield a rechargability of more than 17 cycles, and provide a total battery weight of less than four pounds.

Several configurations using the LR-6 silver-zinc cell were studied. The first iteration of the study resulted in a three stack battery configuration. The three voltages are 1.5V, 6V, and 15V. This configuration required only 15 cells of the LR-6 and resulted in a total weight of about 2-1/2 pounds (.93 Kg).

2-6.2 Test and Evaluation Program

The test and evaluation program involved establishment of a cell testing protocol, procurement of cell samples, and design of an automated cell tester.

The test protocol characterizes cell operation over ranges of temperature, physical orientation, and discharge. Measurements to date have defined, or are confirming, cell performance under ten environmental extremes which define the test envelope. Since at this time the most satisfactory cell chemistry available for player pack use appears to be silver-zinc cells, their performance in unfavorable physical attitudes

is being verified by test. Discharge temperatures used for evaluation are +35°F, +70°F, and +150°F. Discharge orientations include upright, on-side, and inverted positions. Discharge current used has been .7 Amp per cell and will be revised upward to .95 Amp. To reflect new worst-case discharge estimates, a single conservative charge condition of .4 Amp, upright at +70°F is also under evaluation.

For the present study 15 each of the LR-6 silver-zinc type cells manufactured by Yardney Electric Corp were procured. These are noted for their high density, high energy storage, deep-cycle life, immunity to hostile environment, and resistance to leakage. Test data to date is incomplete but is favorable and does indicate at least a nominal viability of this cell type.

2-6.3 Battery Tester Functional Description

To acquire the large amount of necessary cell test data, a cell tester was designed. Consideration was made of labor savings, the need for a complete and permanent test record, test uniformity, and lowest risk of cell damage during testing. The apparatus described here is presently in use and meets these design goals. Refer to Figure 18, Battery Cell Tester Function.

During tests, each cell is connected to either a charging (CH) current source, or a discharge (DIS) dummy load. The Electromotive Force (EMF) of all six cells, both charge and discharge currents of any one selected cell were permanently recorded on an 8-channel strip chart.

Inputs governing the tester's operation are: selection of the cycle desired (CH/DIS SELECT), the present upper and lower test levels (EMF limits), manual and automatic cycling commands (Normal Start/Stop), and a test abort signal generated by any comparator failure in the EMF sampling logic (malfunction stop). These input signals control the charge and discharge relays. A charge cycle continues until all cells under test have charged up to the upper assigned EMF limit. A discharge cycle continues until any single cell has discharged to the lower assigned EMF limit. During normal tests only one of the two relays is

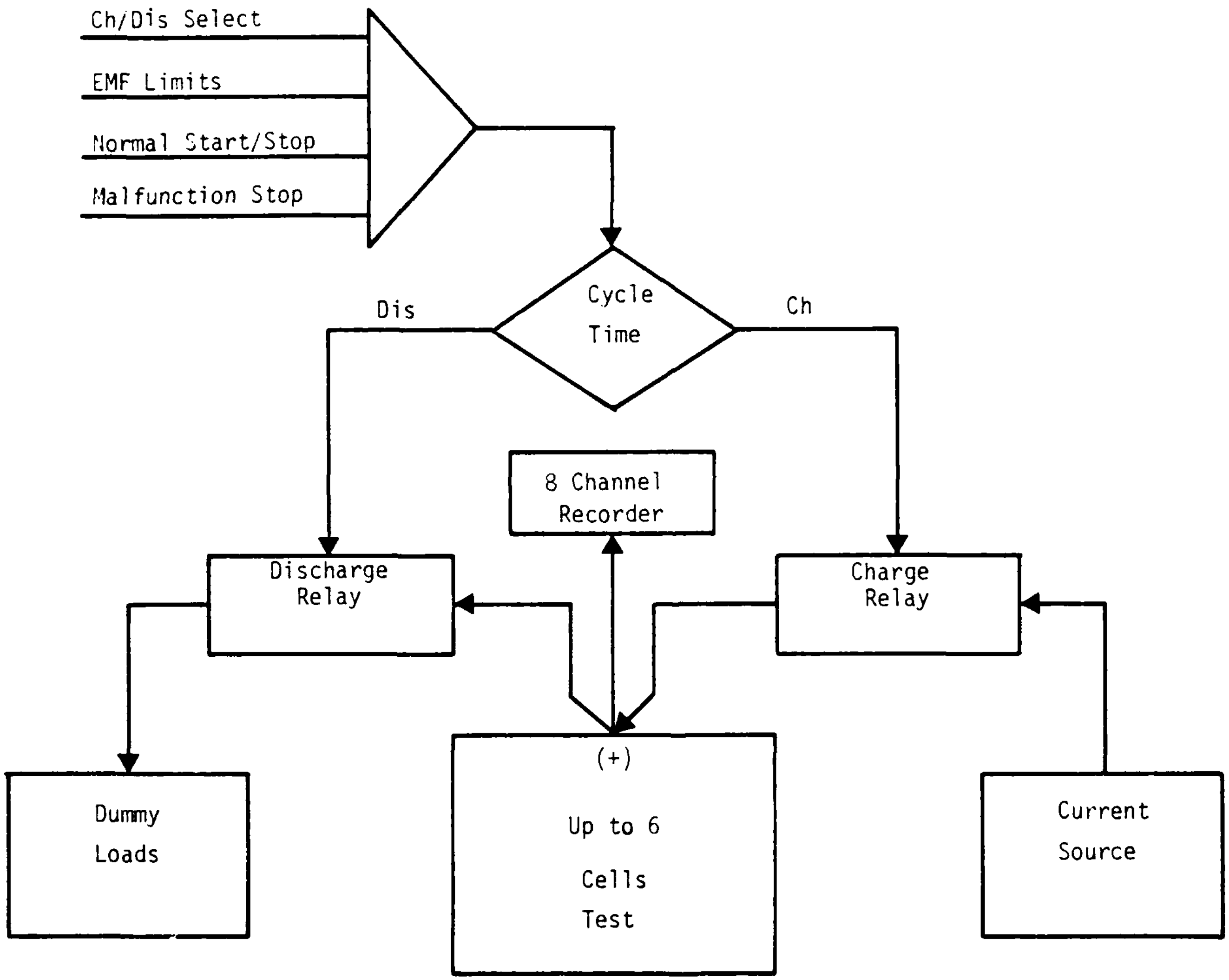

Figure 18. Battery cell tester function.

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energized. A malfunction inhibits both relays, isolating all test cells from the tester. The strip chart recorder increments at 5-minute intervals and records both during charge and discharge test cycles.

2-6.4 Voltage and Current Regulators Functional Description

A set of voltage and current regulators were designed and prototyped for use with the three stack configuration. These yielded an average power conversion efficiency of almost 80 percent, providing +12V DC regulated, +5V DC regulated, and a 500mA regulated current source to the boards under test.

As the circuit design for the player pack boards evolved, so did the power consumption estimate. It appeared that several unforeseen circuit alterations could greatly influence the load requirement on each of the three battery stacks. At this point it was decided that a better approach to the power source would be to incorporate a single stack of cells with an EMF of 15V DC. All of the regulated voltages and currents will be derived from this stack using high efficiency switching type regulator circuits. Using a single stack has several advantages:

(1) The complexity of the battery charging station can be decreased,
(2) The maintenance of detecting bad cells in the stack and fuse replacement is lowered, and
(3) The battery monitoring circuitry becomes much simpler.

Two switching regulators have been designed and are presently under test. They are: (1) a 75 to 80 percent efficient +5V DC regulator for the logic circuits, and (2) a 55 percent efficient 500mA switching current source (this is required for the I^2L microprocessor). There will not be a +12V DC regulator for use by the circuit boards, but rather the unregulated battery voltage will be distributed to each slot requiring on-board regulation if needed.

Figure 19 shows the functional block diagram of the power supply. The batteries are short circuit protected by a fuse which is mounted in the battery container. A connector supplies the wiring to

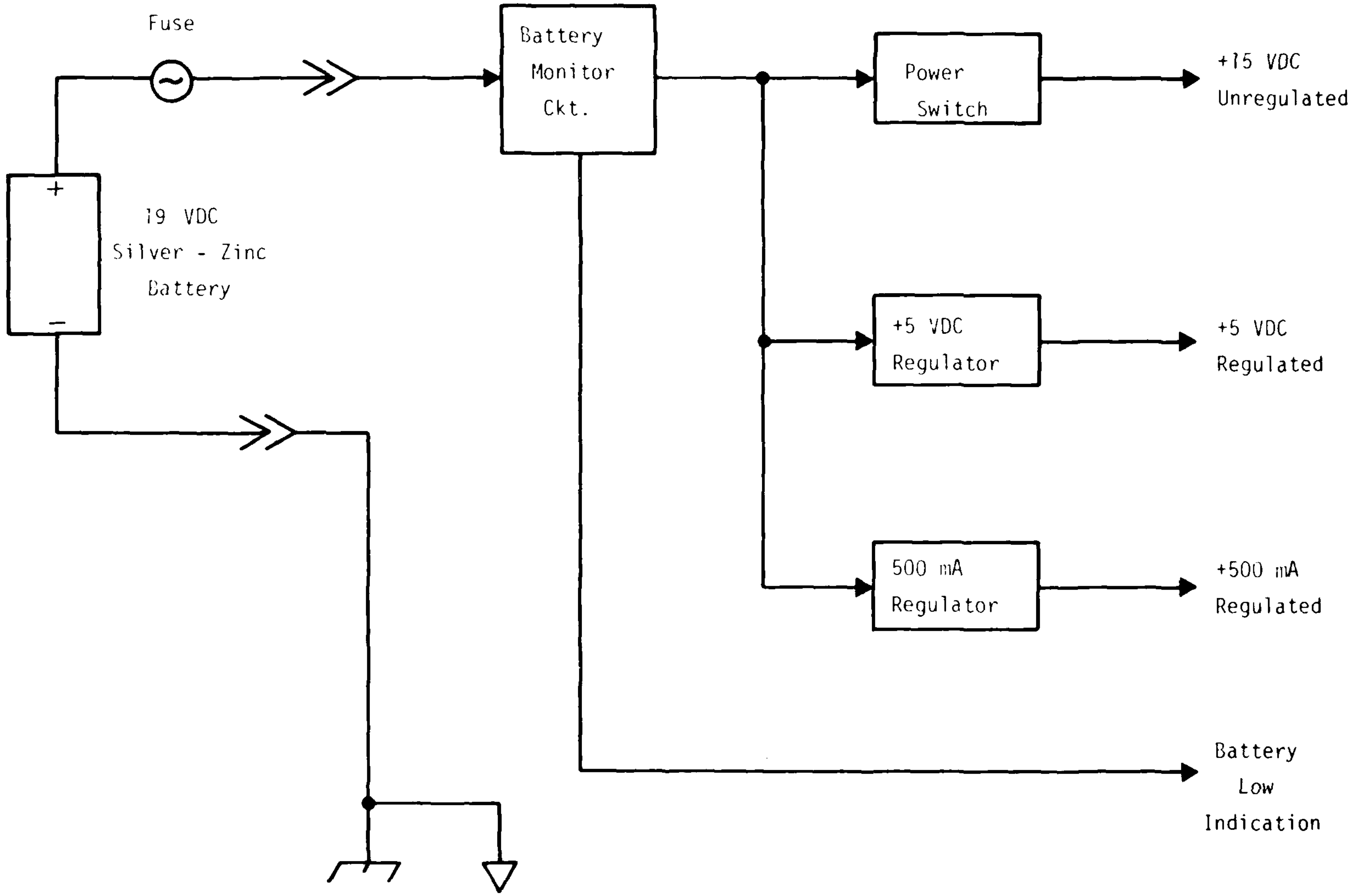

Figure 19. Power supply block diagram.

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the motherboard circuits. A monitor circuit detects the critical discharge depth for the batteries. If this occurs, a signal is sent to the microcomputer informing it of this condition. A fixed time later, the monitor turns off the regulator circuits and power switch to prevent battery discharge beyond the critical voltage.

The regulator circuits, along with the microcomputer system boards, will be tested and verified to operate up to 170°F.

2-7 RF SUBSYSTEM

The RF subsystem in the TNF S^2 instrumentation application will perform three distinct functions: bi-directional communications between the various players and the master station, transponder position location which provides high accuracy positional data, and direct ranging to allow slant range measurement between an attacking player and a target player. Each subsystem will be discussed in detail below. To achieve this function, each player will use an RF transponder to transmit and receive RF pulses and an RF Communications Interface Unit (RF CIU) to encode and decode messages from ECS.

The RF subsystem will be comprised of three pieces of hardware: an RF transceiver which transmits and receives RF pulses, a message encoder/decoder, and a transponder card. The RF transceiver is being built by Vega Precision Laboratories, Vienna, Virginia. The message encoder/decoder (RF CIU) is being built by International Laser Systems, Orlando, Florida. (This is an identical card to that being used in the weapons effects subsystem). The transponder card is being developed by The BDM Corporation.

2-7.1 RF Communication Subsystem Functions

The RF communication subsystem will provide two-way communications between a central control facility and various system player packs. To achieve these three functions, the RF transceiver in the player pack will be time shared between the player's RF CIU and the transponder position location board as directed by the master station. System flexibility is maintained through message protocol (handshaking) and performance is optimized through the internal organization of the master station and player packs.

To maintain system flexibility, the master station will control all communications. When the master station desires information from a player pack, it will send a message to that player pack requesting a response. The master station can send a message to an individual

player pack or to all player packs. When the master station is requesting information from a player pack, the handshaking will be as follows: master station sends a message to a player pack requesting information, player pack responds with that information, master station sends a verification message back to the player pack indicating the receipt of valid data.

The heaviest use of the RF communications system will occur when a "real time" file of test activities is being maintained at the master station. In this mode, most of the RF message traffic will fall into the category of "player tracking." That is to say, the master station will sequentially poll player packs for their position (x, y, and z) and status (wounded, prone/standing, etc.). The player pack response will include a bit which will tell the master station if the player pack has any event data to send (events will be such things as weapon engagements, etc.). If a player pack response indicates event data is available, the master station requests an event message. Thus, if a player pack had two events to report, the handshaking would be as follows: (1) request tracking messages, (2) send tracking data/have event data, (3) request event message, (4) send event message/more event data available, (5) request event message, (6) send event message/no more event data available, (7) send verification. Note that each request for further data verifies receipt of the previous message.

All messages from the master station will consist of 36 bits, and all player responses will consist of 72 bits.

The system performance will be optimized by minimizing the turn around time between reception/interpretation of one message and transmission of the next. In the master station this will be achieved by using fast, high power hardware. On the players this will be achieved by having them anticipate the type of message that will be requested by the master station, calculate CRC (cycle redundancy check) on the message, and preload it into a buffer which can be transmitted immediately upon request from the master station.

2-7.1.1 RF Message Duration

Each RF message will consist of two start pulses and a series of information pulses. Each information pulse will contain six bits of data. Master station messages will consist of six information pulses, and playerpack responses will consist of 12 information pulses. A typical master station message will be 865μs. This number is predicated on the message encoding being chosen so that certain bits are always zero.

Player pack messages, on the other hand, are almost completely unstructured in that any of the bits can be high or low, depending on message content. The time analysis assumes that all bytes are sent in the player pack messages. With this in mind, the timing for a player pack message will be as follows: two start pulses -- 80μs, 12 information pulses of 149μs each, total transmission time is 1.868ms.

With the handshaking protocols chosen, there will be two types of time cycles. The first time cycle will be the RF message traffic associated with a tracking message, and the second cycle will be the messages associated with an event. Each tracking message sequence will require 4.6ms and each event message sequence will require an additional 3.7ms.

2-7.1.2 System Load Due to RF Message Traffic

To calculate the total load on the system due to RF messages, let us assume that there are 100 slow players and 10 fast players being tracked. The player packs on the slow players will be queried once every two seconds, and the player packs on the fast players will be queried five times a second. Thus, over a two second interval there will be 150 tracking cycle interactions. Further, let us assume that the slow players have a total of 100 events which occur to them as a group in any two second interval. Based on these assumptions, the total system load can be calculated as shown in Table 3.

TABLE 3. SYSTEM LOAD FROM RF MESSAGES

MESSAGE TYPE	TIME PER MESSAGE	NUMBER OF MESSAGES	TOTAL TIME
Tracking	4.60ms	150	.69s
Event	3.70ms	110	.407s
	Total during a 2 second interval		1.097s
	(duty cycle 54.9%)		

2-7.2 Transponder Position Location Subsystem

The transponder position location system will be the high accuracy locating system of the TNF S^2 instrumentation. The system will work by having players measure their range from transponders which are located around and within the playing area. By knowing their range from the transponders and the x, y, z coordinates of each transponder, each player can perform its own position location calculations.

The system will work by having each player assigned a specified time window wherein it can address the transponders. Within its window the player will sequentially address all of the transponders and make the range measurements. A player will address a given transponder by transmitting two RF pulses. The spacing between the RF pulses will contain the address information for the transponder being addressed. When a transponder hears its address it will wait for a fixed amount of time and rebroadcast its address (two pulses). The player will measure the range by measuring the elapsed time from when it transmits the second address pulse until it receives the second returned address pulse. The precision of the range measurement will be one meter.

The transponder position location will be time shared with the RF communication function. This will be done by having the master station tell all the players and repeater stations when to convert into the transponder position location mode. This sequence is detailed in Figure 20. Note in this figure that the master station is controlling all RF communication. When the master station decides it is time for

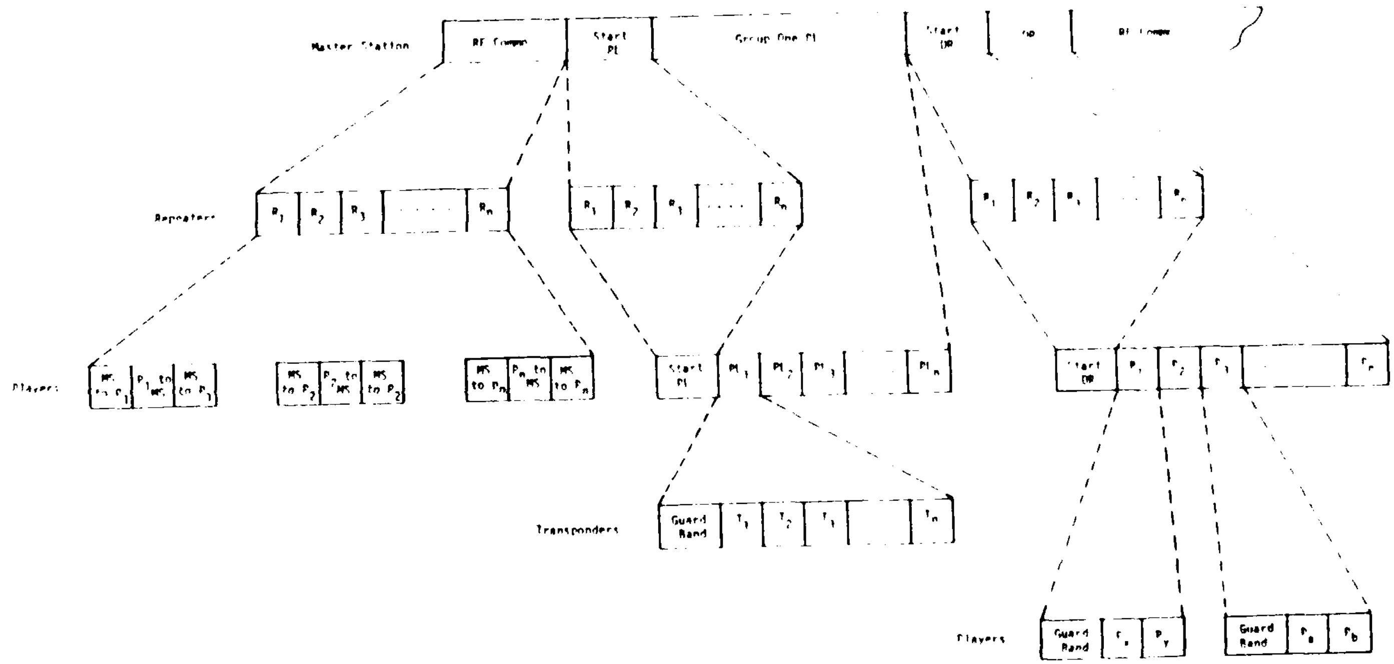

Figure 20. Transponder position location system.

the system to do a position location update, it will send an RF message which will tell a group of players to get ready to do position location. When a repeater/transponder interprets a message which says position location is about to start, it will repeat that message and switch to a "look for start" mode. Similarly, players will interpret the message, initialize their transponder PL boards, and go into a look for start condition. Once the master station has determined that sufficient time has elapsed for the player and transponder hardware to be initialized, it will send out two RF pulses. These two pulses will have the effect of starting the transponder PL cycle. When the repeater stations hear these two pulses, they will repeat them and immediately switch to the transponder mode of operation. Similarly, when players hear these two pulses, their transponder position location card will immediately start operating. Each player of the group that is to do position location will have a time window assigned. The transponder position location card will automatically measure the elapsed time until the players assigned window occurs. During its window, the transponder PL board will wait for a guard band and then sequentially address each one of the transponders and measure the range.

2-7.3 Direct Ranging

Direct ranging will be similar to transponder position location in that, under direction of the master station a direct ranging cycle will be performed. During this type of cycle, each player will be given a window in which it can perform ranging measurements. In its window, a player will be able to measure range between itself and two other players. This function will be achieved by having the player act as a transponder for most of the cycle and switch to an interrogator during his window. This allows other players to perform range measurements to a player when it isn't performing measurements itself. This type of measurement will be useful in intervisibility determination and attacking/target player slant range determination. In a 50-player test, a direct ranging cycle would require approximately 20ms.

2-8 Weapons Effects Subsystem

In order to provide combat realism during mock live-fire engagements, a man-safe simulator for direct fire weapons is required. Bore sighted lasers have been used in the past to provide this function. In this approach, weapon mounted electronics detect a muzzle flash and transmit a coded laser message. Each player has several laser detectors to sense an illumination. Such systems have traditionally suffered from two fundamental operational problems (1) during close-in engagements it is possible (likely) that the small diameter laser beam will miss all of the discrete sensors resulting in no detectable "hit" at nearly point-blank range and (2) reflections from walls and floors will result in "erroneous" hits. Both of these detract from operational realism.

The objective of this task is to provide a safe, realistic weapon simulator. The system should work from "point blank" range to at least 2KM.

The weapon effects subsystem is being developed by International Laser Systems of Orlando, Florida. Part of the subsystem will also be used to encode and decode messages in the RF communication subsystem.

2-8.1 System Operation

The players will fire actual weapons using blank rounds. Everytime a player fires a blank round, the weapon effects subsystem will transmit a coded message using an eye-safe laser, mounted to and bore sighted with the barrel. When a target player sensor is illuminated by an incoming laser message, the playerpack electronics will automatically decode the message and pass the information along to ECS. ECS will then make the Real Time Casualty Assessment (RTCA) decision based on the content of the laser message and will inform the player when he has been shot at and near missed, wounded, or killed. Thus, realism is gained by using actual weapons with blank rounds and weapons effects are simulated through the use of coded laser messages.

The weapons effects subsystem will be composed of three primary elements. The first element will be weapon mounted electronics. This will consist of electronics to detect the firing of a blank round, to communicate that information back to the rest of the subsystem, and to fire the weapon-mounted laser on command. The second element of the system will be the harness-mounted light detectors. This will consist of both discrete and area sensors that are mounted on a player's uniform. When incoming light is detected by any one of the sensors, signal lines will communicate this information back to the Weapons Effect Communications Interface Unit (WECIU). The third element of the system will be the WECIU that will coordinate the activities of the weapon- and harness-mounted electronics, encode messages, decode messages, and communicate with ECS.

When a round is fired, the weapon-mounted electronics will detect the muzzle flash and will notify the WECIU that a round has been fired. When this occurs the WECIU will generate an interrupt to ECS to inform it that a round has been fired. ECS will log that a round was fired at a certain time and will give a transmit command to the WECIU.

When the WECIU gets the command to start the transmission, it will generate and transmit the proper pulse sequence for the message to be transmitted.

At the target player, every time a laser pulse is detected the light detectors will immediately send a digital signal to the WECIU. The WECIU will decode the incoming pulse train to determine if it is a valid message. When the WECIU has decoded an entire message and has determined that it is valid, it will store the message in its own buffer memory and generate an interrupt to ECS to tell it that a message has been received. ECS will then transfer the message into its memory, make the appropriate RTCA decision, and log all of the information in its data file.

Two additional functions performed by the weapons effects subsystem will be: (1) determine which part of the body was illuminated,

and (2) determine when a "wide light pulse" occurs. The wide light pulse will be used in future system additions to detect the occurance of an explosion from an area weapon such as a hand grenade.

2-8.2 Unique Characteristics

Several unique features are being incorporated on the TNF S^2 weapons effects subsystem. One of these is the use of area light detectors. These will be arrays of fiber optic material that will be sewn onto the players uniform. All of the fiber ends will be routed to one detector. Thus, whenever a laser illuminates any part of the area detector, the light will be detected. The area detectors will be useful for close-in combat where the laser beams will be fairly small and could hit any part of the body. By having area detectors, a hit anywhere on a players uniform will be detected. The area detector's long range sensitivity is not as great as discrete detectors. Therefore, at least one body area will have both an area detector and a discrete detector. The area detectors will be primarily useful for close-in engagements, and the discrete detectors primarily for long range interactions.

One unique benefit of having both area and discrete detectors will be that it provides the mechanism to discriminate against close-in shots that have been reflected off of a wall or floor. With present systems it is possible to aim at a wall near a player and get enough reflected light to trigger his sensors and score a hit. In the TNF S^2 system, this effect can be discriminated against using the difference in sensitivities of the area and discrete detectors. If two players are close together and the laser has been reflected off of a wall, the light energy will be scattered. There will be sufficient energy to energize the discrete detector but not the area detector. Thus, when a player is illuminated and the player pack determines that the slant range from the weapon is fairly small, the area sensors can be polled. If no area sensors registered a hit, then it is a safe assumption that the laser beam was reflected before it illuminated the player.

Another unique aspect of the weapons effects subsystem is that there will be no hard-wired link between the weapon-mounted electronics and the WECIU. Communication between these two elements will be over a bi-directional proximity link. One half of the proximity link will be mounted on the stock of the weapon being fired, and the other half will be attached to the players hand. The characteristics of the link will be such that the players hands must be within a couple of inches of the weapon or the weapon cannot communicate to the WECIU. This will allow free play in a battle so that a player can fire any weapon. This bi-directional link generated two issues which had to be addressed in the design. First, the weapon must tell the WECIU its type every time a round is fired, and there must be positive feedback to a player so that he knows for sure that his laser is firing. The first issue is resolved by having the weapon-mounted electronics transmit two pulses when it detects a muzzle flash. The separation of the two pulses will contain the weapon type. The second issue is resolved by having the player's sonalert give a beep every time the WECIU board transmits a message. Thus, when a player pulls his trigger, he will hear his blank round fire and that will be immediately followed by a short beep from his sonalert.

A conceptual diagram of how the weapons effects elements will be integrated into the playerpack is shown in Figure 21.

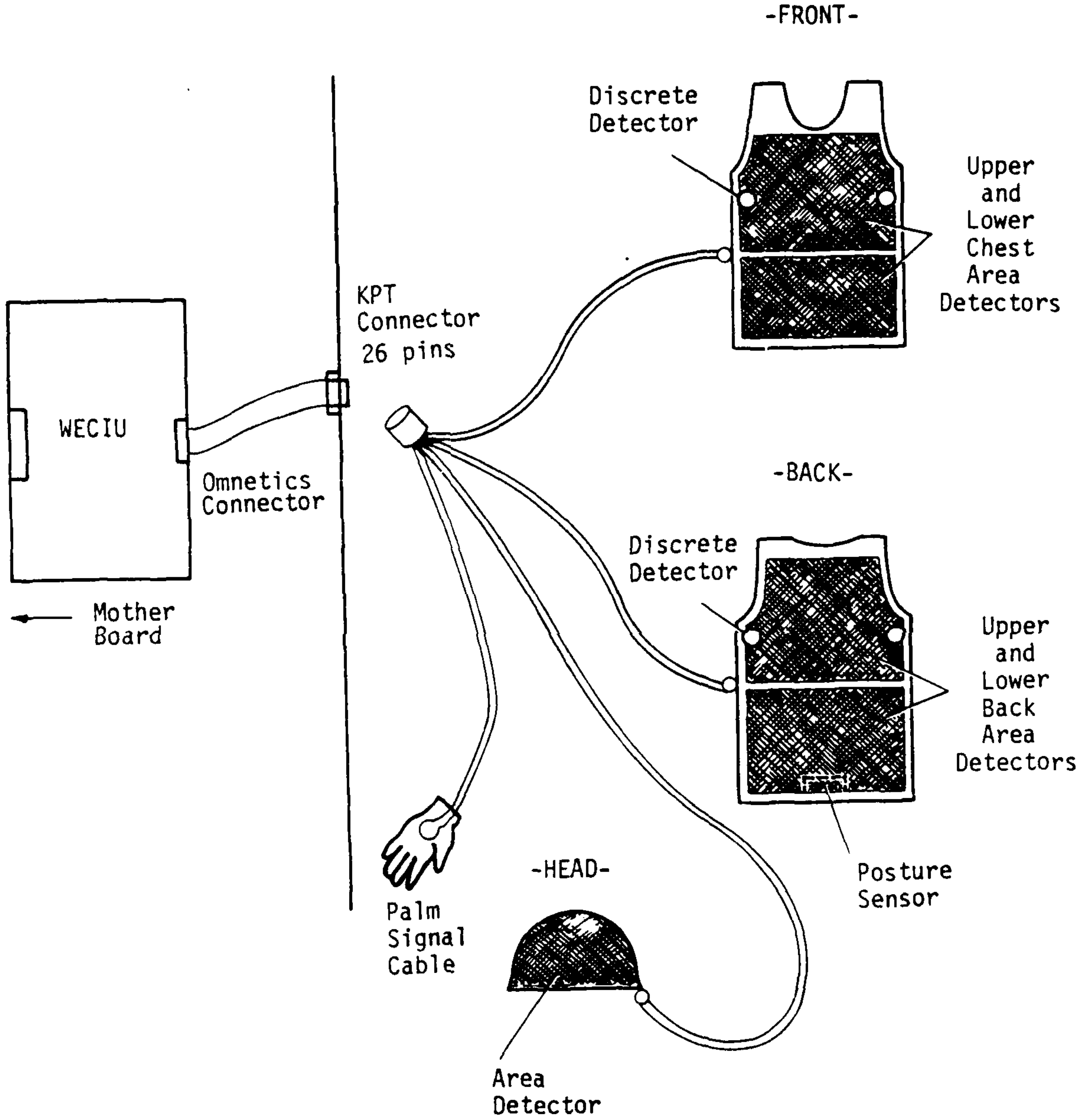

Figure 21. Weapons effects subsystem elements.

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2-9 PACKAGING

The packaging task consists of providing a suitable enclosure, appropriate harnessing or mounting, and adequate power supplies for the TNF S^2 elements under consideration. There are currently three identified elements which require an extensive packaging effort. These are: (1) the player pack, (2) the repeater stations, and (3) the master station, which will be discussed separately. Each of these elements have different environmental, functional, and logistics constraints that impact the packaging concepts.

2-9.1 Player Pack Units

The player pack must be equipped with a hardness engineered for comfort over long periods of use. The electronics package must be provided with a light-weight, weather-tight enclosure. This enclosure must allow easy access to the electronics for maintenance while providing protection against water, mud, dirt, etc. Batteries and battery compartments must be provided as a part of the enclosure (refer to Figure 22, prototype TNF S^2 player pack).

A market survey revealed that a commercial backpack harness and frame, suitable for the player pack, was available. The harness and frame was mounted to a realistic mockup model of the player pack. The harness was evaluated and decisions were made to also evaluate a soft pack, as another option. A soft pack would consist of foam cut to match the contour of the soldiers back and the player pack would in turn be mounted to the foam enclosed in canvas.

A prototype unit of the card cage that holds the circuit boards internally to the electronics enclosure was fabricated and evaluated. It was found that if certain modifications were made, the player pack could be reduced in both size and weight. The modifications were: (1) to move the RF unit out of the main card cage section to be mounted on the outer interface panel along with external connectors (refer to Figure 23), (2) the circuit board slots were re-arranged so

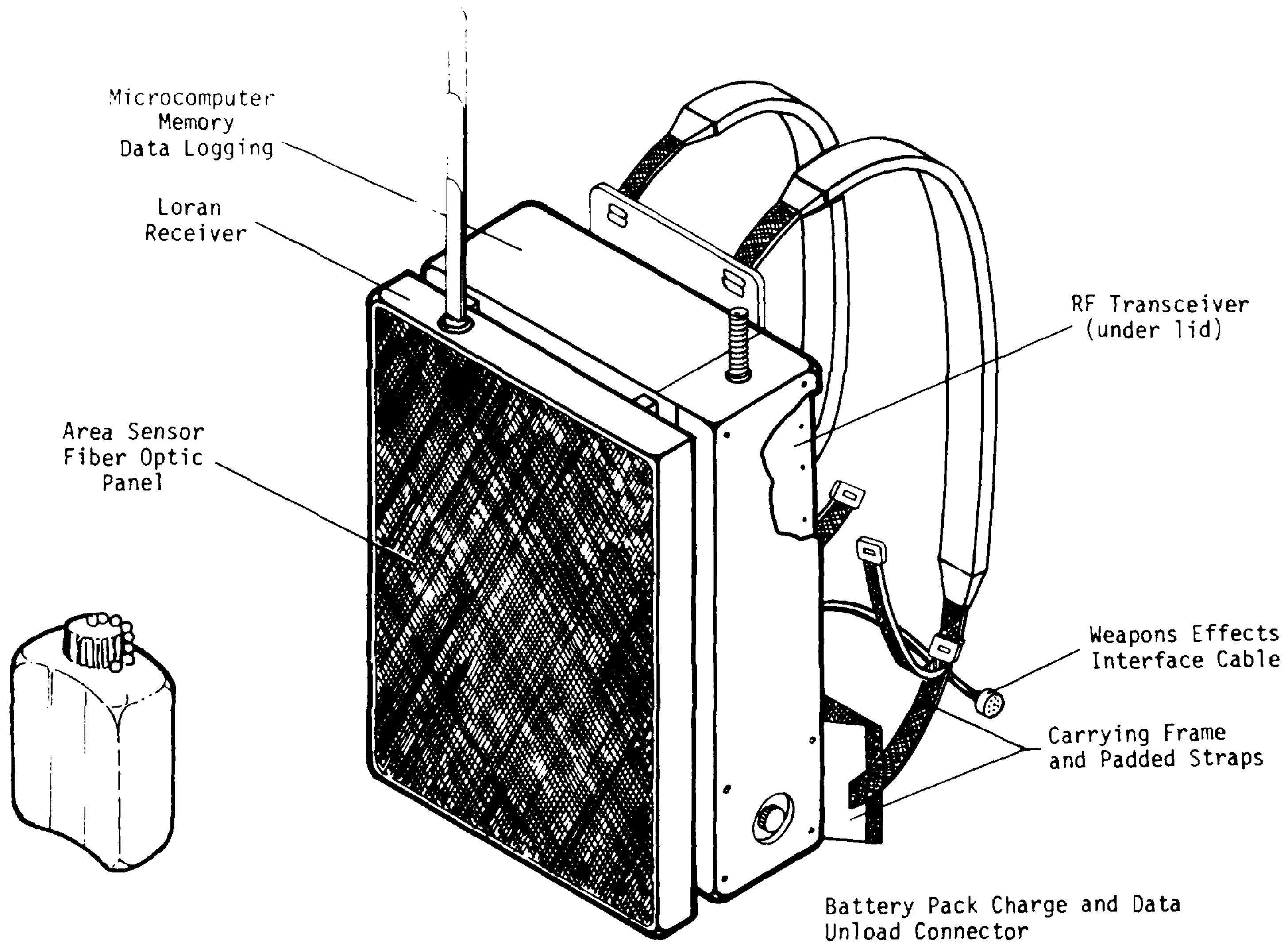
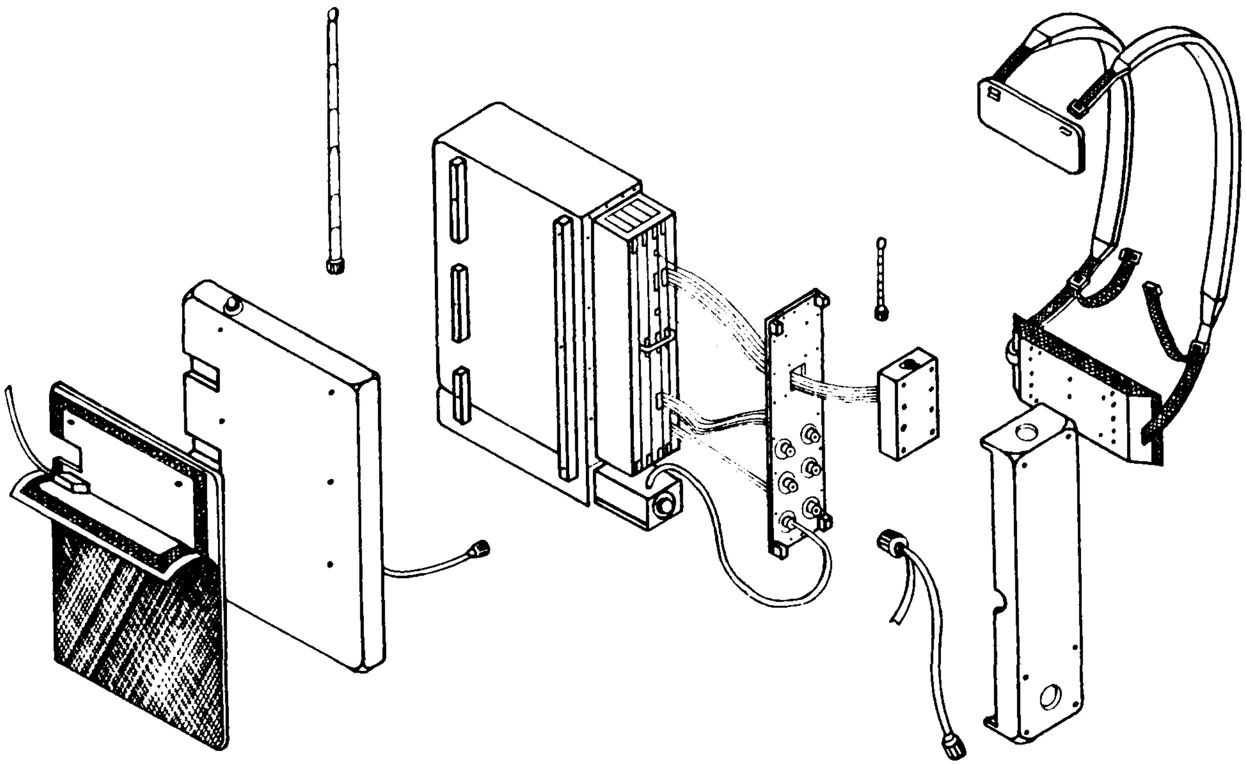


Figure 22. TNF-S^2 prototype player pack for footsoldiers.



BDM/TAC-79-611-TR

Figure 23. TNF S^2 prototype player pack configuration.

that the Data Logging Subsystem utilizing a cassette recorder could be replaced with bubble memory or bulk CMOS RAM, and (3) the motherboard was re-designed so that the Universal I/O module could be placed into any slot other than the microcomputer slot. The modified card cage has been fabricated and will now undergo extensive testing and evaluation.

The outer prototype electronics enclosure design is complete. The enclosure will be fabricated shortly, allowing for further evaluation and testing of the design.

2-9.2 Repeater Stations

The repeater station has the same environmental requirements as the player pack. However, it need not be comfortably harnessed. Additionally, an antenna mast (VEGA) must be provided. Batteries for the repeater need not be the same as for the player pack.

An initial design concept has been formulated for the repeater station in order to place orders on long lead-time parts. No prototype units have been fabricated to date. The batteries will initially be a low maintenance lead-acid battery to supply the higher power required.

2-9.3 Repeater/Transponder Towers

The towers themselves are a lightweight, collapsable-type, constructed with aluminum in a lattice structure. They will be deployed by a two-man team for installation once the testing area has been surveyed (refer to Figure 24, Repeater tower). The top of the tower will support the antenna, transmitter power amplifier, and receive preamplifier. The remaining electronics will be housed in a weatherproof container along with the batteries at the bottom of the tower. With this configuration it is reasonable to expect a maximum payload of 25 pounds for the tower. For a 50-foot tower weighing approximately 25 pounds, system integrity will be maintained in winds up to about 80 miles per hour. For permanent installations, heavier towers will be used and wind velocities of over 140 miles per hour are easily withstood.

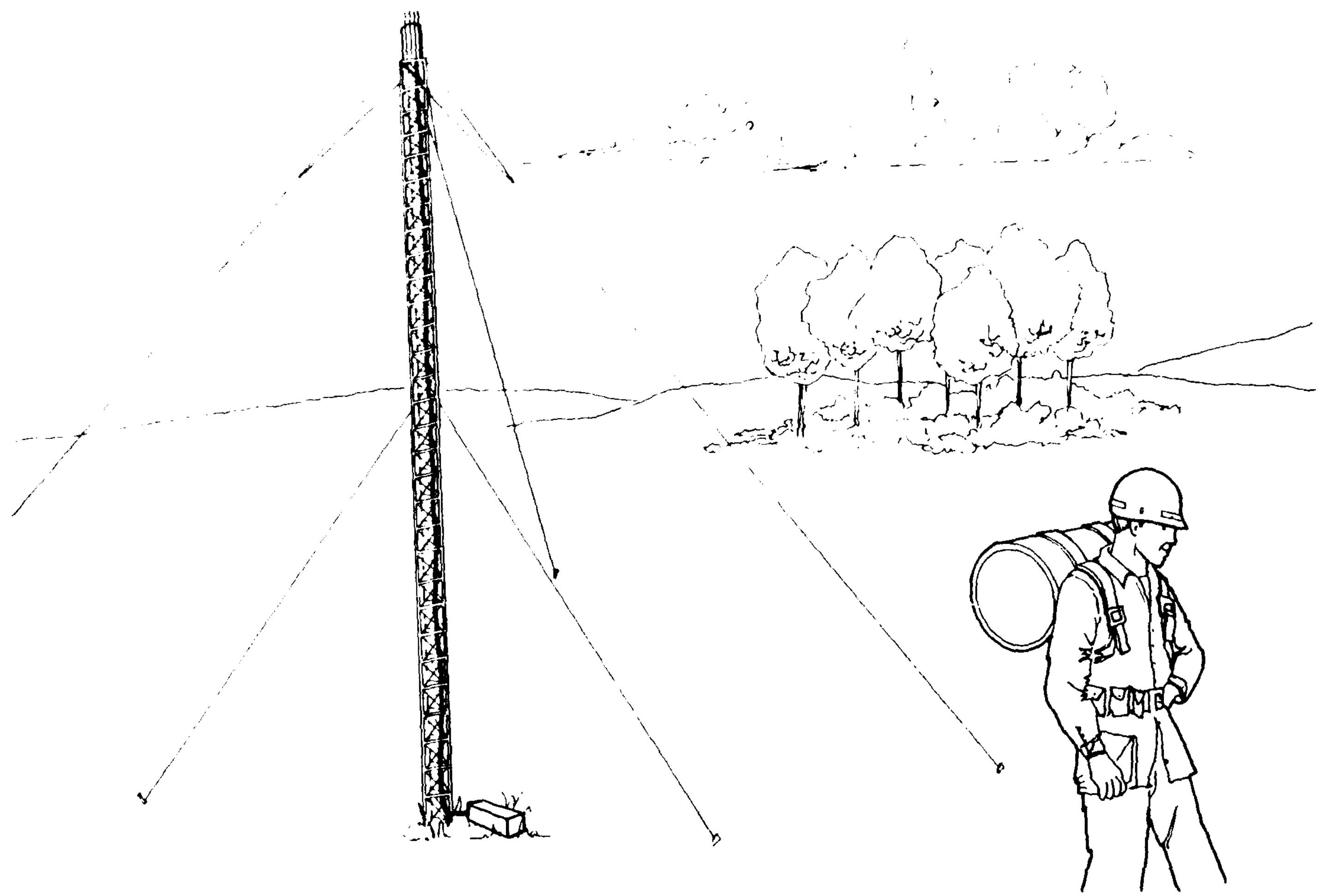


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Figure 24. Repeater tower.

2-10 MASTER STATION DESIGN

The preliminary design of the master control shows it to consist of three trailers: an operations and maintenance trailer (O&M), a player preparation trailer, and a weapons and ammunition storage trailer. The design calls for the trailers to be air transportable by either two C141s or a C-5A. The eight by forty foot O&M trailer will be provided by a subcontractor. The acquisition of the other two eight by twenty foot trailers is anticipated to be through GFE (FSN-8115-168-2275). The trailers will either be equipped with a removable under-carriage or will be transported on flat bed trailers.

Figure 25 shows a possible configuration of the O&M trailer. This trailer van is the data acquisition system and control center during the field tests. The design calls for the trailer to be divided into three areas -- an operations area, a maintenance area, and an area for the environmental control equipment. The environmental control equipment, consisting of an air conditioner, heater, humidifier, power conditioner, and power distribution system would be housed in one end of the trailer, as shown in Figure 25. The equipment would be acoustically and thermally isolated from the rest of the trailer. Access to this area would be through double doors at the end of the trailer.

The remainder of the trailer would be the operations and maintenance areas. Field level maintenance of player packs and associated hardware would be conducted in the area indicated in Figure 25. The area would contain the equipment necessary to conduct this level of maintenance including a workbench, equipment rack, and several storage cabinets. A nonrigid divider such as curtains would be used to separate the lighting levels between the maintenance and operations areas. The operations area would contain the computers and all hardware necessary to support the player packs and transponders. A preliminary list of equipment includes three video display terminals, a line printer, a digitizer, two equipment racks, and two computer racks.

Figure 26 shows the player preparation trailer, along with the weapons and munitions trailer. The player preparation trailer will contain the laser detector equipped helmets and suits, the player packs, spare player pack batteries, the battery recharging system, and the data unloading system. The proposed layout of the trailer will be such that the players could walk in one door of the trailer, put on each of the required pieces of equipment, exit out the other door of the trailer, enter one door of the trailer, be issued the weapons, and then exit. The separate weapons trailer is used to provide the necessary security.

Figure 27 shows a possible deployment of the three trailers. The area bounded by the trailers will be lighted by flood lights attached to the trailers and will also be serviced by a public address system. A verification system will be placed as shown in Figure 3, outside the weapons trailer. As the players exit the trailer they would stop at a designated spot, fire their weapon at a sensor target verifying their weapon, and then their sensors would be verified by a laser associated with the target.

The preceding outline of the configuration and deployment of the individual trailers is preliminary and subject to change. The concept behind each of the trailers should not change; only the details of the equipment placement may be expected to change pending decision on the exact trailers to be used.

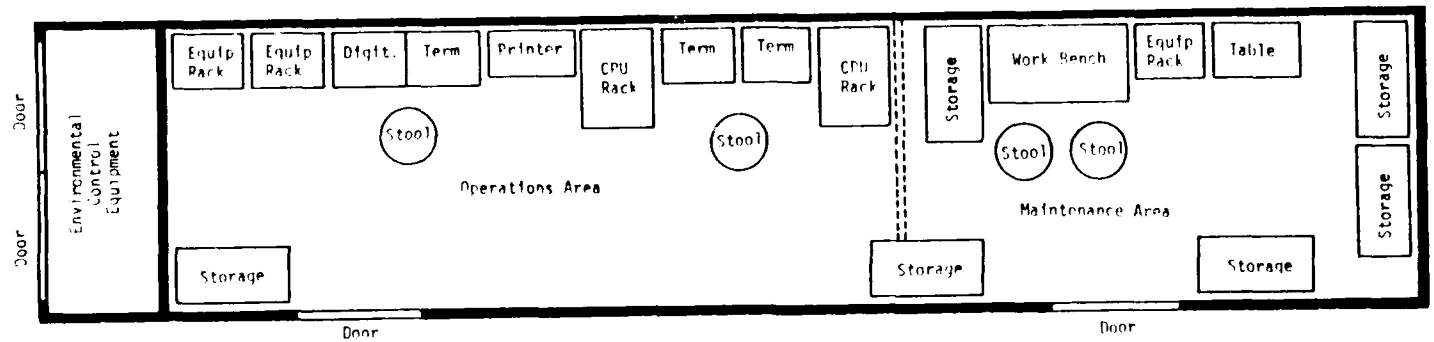

Figure 25. Operations and maintenance trailer.

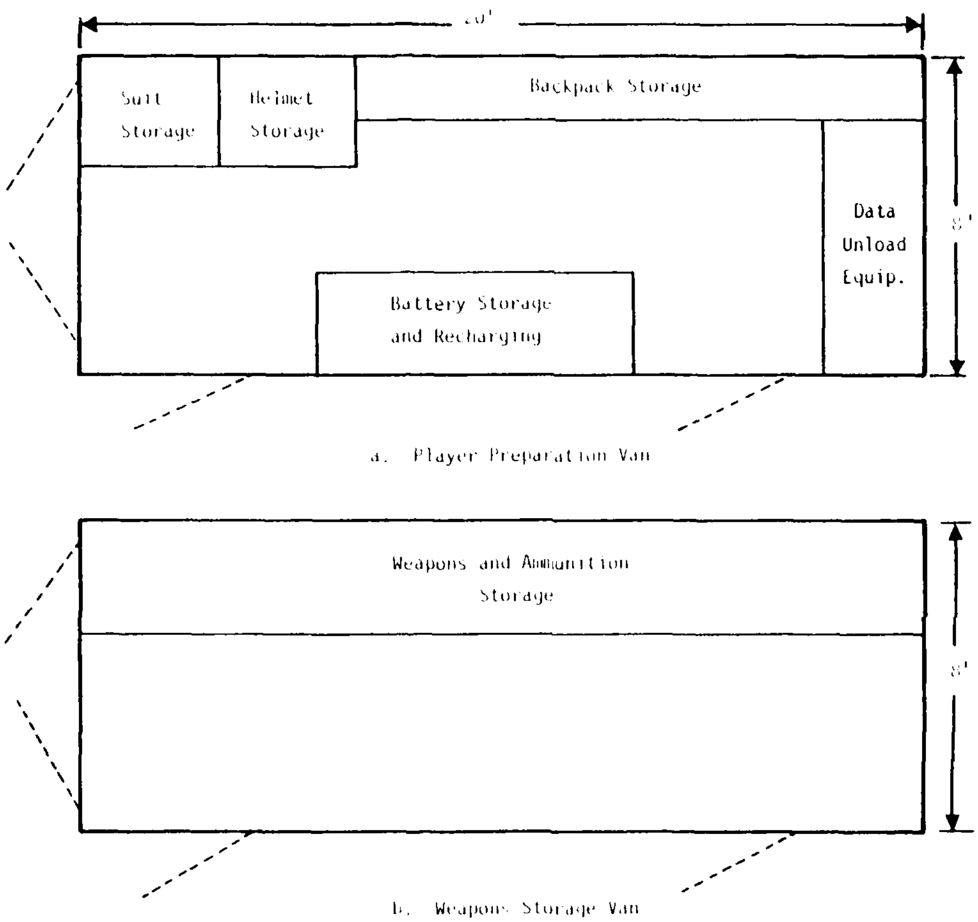

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Figure 26. Master station support van.

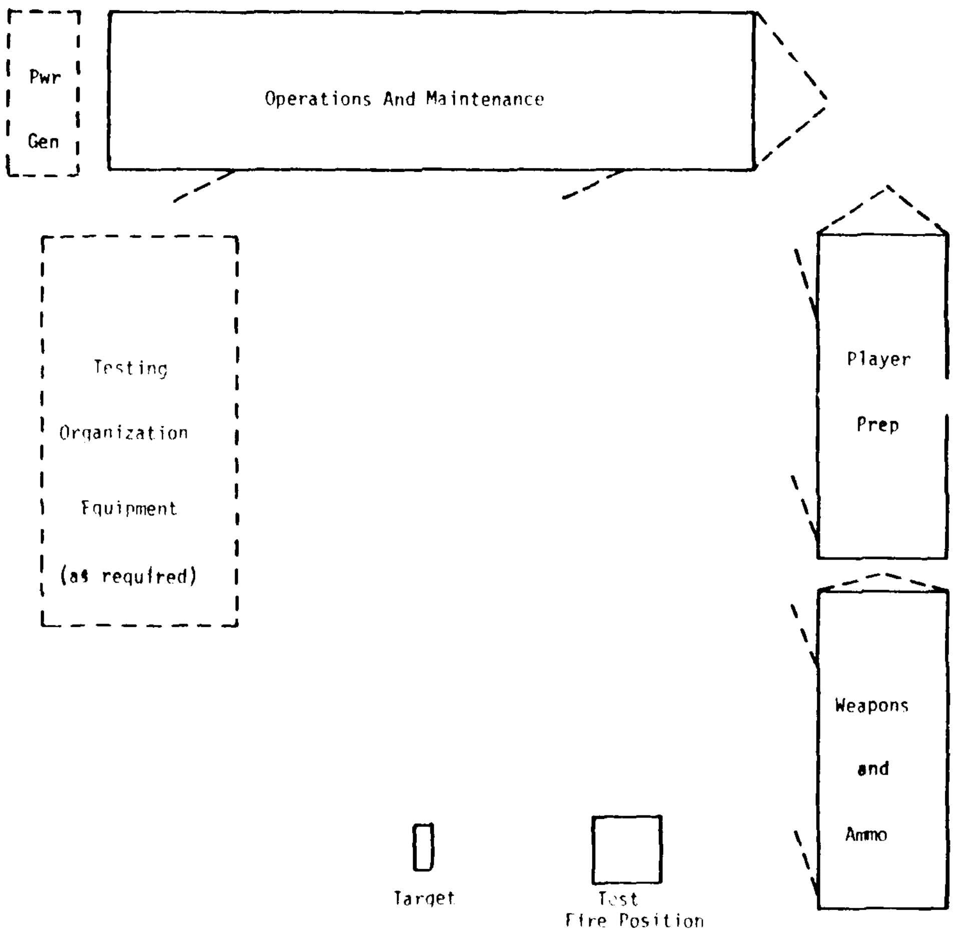

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Figure 27. Master station deployment.

SECTION III
SOFTWARE DEVELOPMENT

3-1 INTRODUCTION

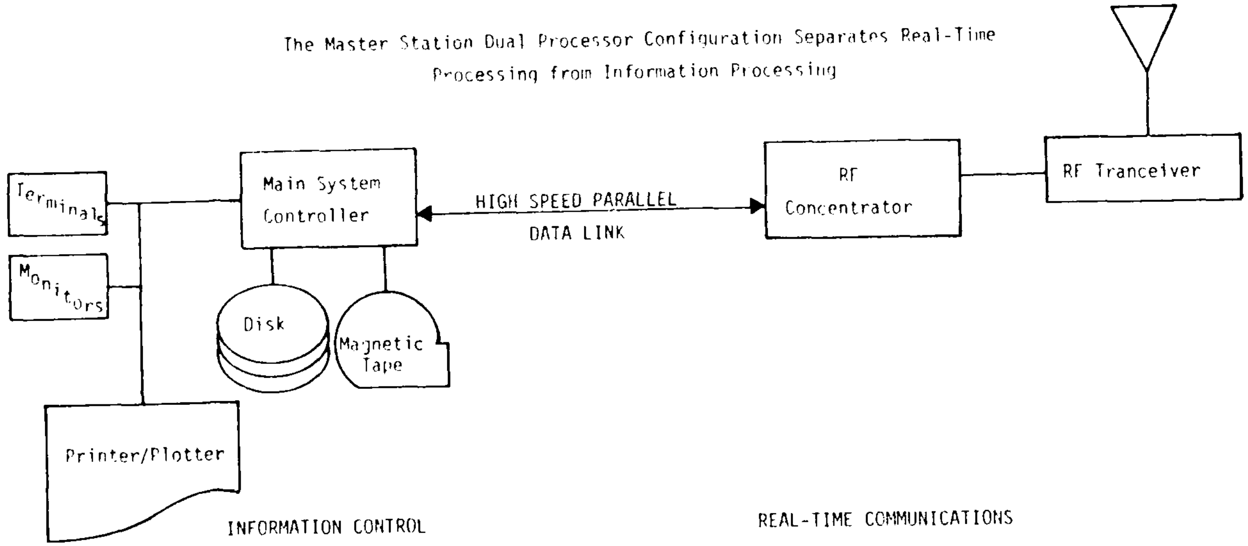
Several things have been done in defining the TNF S^2 instrumentation system which will minimize the recurring costs of software development. First, whenever possible, vendor supplied software is used. Second, all software is produced using modular, top-down structured programming. This makes the software traceable and flexible. It can be easily and quickly modified as the situation demands. Finally, the master station and the player packs share a common instruction set. This commonality is true at both the coding and object level. This commonality is somewhat unique and vastly reduces the total programming burden as well as providing module transportability. Such transportability is only moderately achievable using High Order Languages if the object code compatibility condition is not met.

3-1.1 Master Station

The master station software is quite straightforward, although many of the details remain to be worked out. As shown in Figure 28, the basic master station consists of two processors, one acting as a concentrator for the communication system. This dual-processor system will be integrated using vendor-supplied, commercially available interfaces. The concentrator will handle all RF system related processing and provide data in burst mode to the main controller for recording and display. All software for the concentrator remains to be developed, but will be done in such a way that, in the event of a catastrophic failure, it can be loaded in main controller although the master station will then operate at a somewhat reduced efficiency.

The software for the main master station controller, produced by Texas Instruments, will run under the T.I.'s commercial operating system (DX10). This will reduce the effort significantly compared to stand-alone software production.

The Master Station Dual Processor Configuration Separates Real-Time Processing from Information Processing



INFORMATION CONTROL

- Data Recording
- System Status Monitor
- Player Status Monitor
- Operations & Maintenance
- Logistics

REAL-TIME COMMUNICATIONS

- All Player RF Communications
- All Real-Time Processes
- Data Encoding/Decoding
- Data Formatting

Figure 28. Master station controller.

BDM/TAC-79-611-TR

The basic hardware for both the master station controller and the RF concentrator will be identical, thus significantly reducing the spare parts logistics.

3-1.2 Player Software

The player pack software is somewhat unusual for a microprocessor-based instrumentation. The extreme flexibility requirements dictate that an operating system philosophy be employed. The operating system will be highly modular to allow easy reconfiguration of the specific hardware elements and must isolate the control of these hardware elements so that data transfers can occur reliably, independent of the particular process in progress. Furthermore, processes must be prioritized. This prioritization must occur at two levels: (1) data transfers with peripheral devices must be prioritized on the basis of both the transitory nature of the data and its prospective importance to the player in an operational scenario. For example, laser illumination data is operationally more important than position data since it could result in a simulated player casualty, and (2) computational processes must be prioritized on the basis of relative operational importance.

These requirements lead to the following conclusions concerning player pack software: (1) data transfers to peripherals must be driven by prioritized interrupts, (2) normal computational processes (tasks) are prioritized and execute under control of the operating system, (3) tasks communicate with peripherals via supervisor calls to operating system modules which actually handle the data transfer, and (4) CPU resources are allocated to the most important pending task.

Thus, the player software is divisible into two modular categories: (1) the Executive Control System (ECS) which is a prioritized, interrupt-driven, multitasking operating system, and (2) all computational modules or tasks.

The Executive Control System consists of four major functional elements with an optional fifth element. As shown in Figure 29, these are: (1) the task scheduler which determines which task is currently to

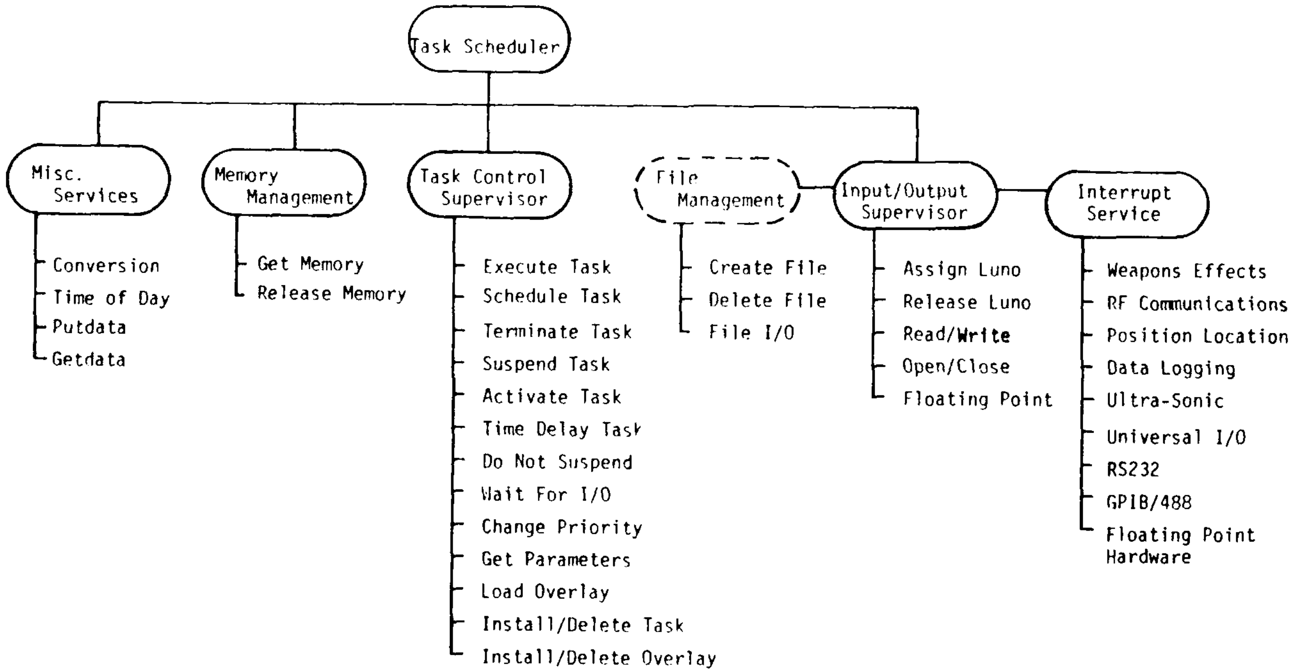


Figure 29. Executive control system architectural overview.

be executed, (2) the memory manager which allocates blocks of memory as required, (3) the I/O Supervisor which maintains the communications between tasks and peripherals, (4) the task control supervisor through which tasks can initiate other tasks, etc., and (5) file management for handling random access files on the mass storage device.

The tasks which execute under the auspices of ECS determine the functional role of the player pack. Tasks can be modularly added or deleted without affecting the remainder of ECS. Such processes as Real-Time Casualty Assessment (RTCA), Position Location (PL), and RF communications are performed by tasks.

3-1.2.1 The Task Scheduler

The Task Scheduler uses a round-robin algorithm to execute tasks resident on four prioritv queues. This algorithm assures both that the highest priority tasks receive the greatest amount of CPU time and that low priority tasks are not totally locked out.

3-1.2.2 Memory Management

To minimize the amount of physical memory required in the player pack, temporary buffers and ECS tables operate in dynamically allocated memorv. This technique makes memory available where and when it is needed. The memory manager is responsible for keeping track of the dynamic memory and allocating it as required.

3-1.2.3 The Input/Output Supervisor

The I/O supervisor consists of a system core processing module and a group of special purpose modules (Device Service Routines or DSRs). Each DSR handles the specific I/O process for a single peripheral device and interfaces to ECS through a rigidly defined protocol. Adding a peripheral to ECS is done by simply installing the DSR into the modular list of the I/O supervisor.

3-1.2.4 Task Control Supervisor

The Task Control Supervisor handles the processes which affect task scheduling and execution. Tasks may cause other tasks to go into execution, suspend their own execution, generate time delays, and other functions required in a multitasking environment.

3-1.2.5 File Management

The file management module is optional. Its use is restricted to player packs using magnetic bubble memories for mass storage. It provides the bookkeeping and control functions for implementing random access files, both temporary and permanent.

3-2 TASK SOFTWARE

Because tasks are isolated from the actual system hardware by the I/O supervisor they can be written without the need to attend to the details of data transfer processes. In fact, the run-time environment of a task executing under ECS is nearly identical to that of a commercial minicomputer. This condition vastly simplifies task software production and very definitely modularizes the total task complement. Tasks can be added or deleted at will with no impact on the remainder of the software. Figure 30 shows the communication paths between Tasks and ECS. No effort has been expended to date which is specifically devoted to any of the tasks, however, a great deal of preliminary work has been done; especially in the area of algorithms for position location and RTCA. Some of the tasks already identified are described below. There will, inevitably, be many additions as process details are worked out.

3-2.1 Real-time Casualty Assessment

RTCA is the primary task in the player pack system. It is here that a player's miss/wound/kill status is determined subsequent to a weapon simulator engagement. RTCA will be handled by a set of tasks in final form. The first obvious division is to provide separate tasks to handle direct fire weapons and indirect fire or area weapons.

3-2.1.1 Direct Fire RTCA

For direct fire weapons a laser simulator is used. Parameters of the casualty assessment are: slant range, weapon type, body area illuminated, firer posture, firer marksmanship, number of previous wounds, and round type. Algorithms based on many of these parameters

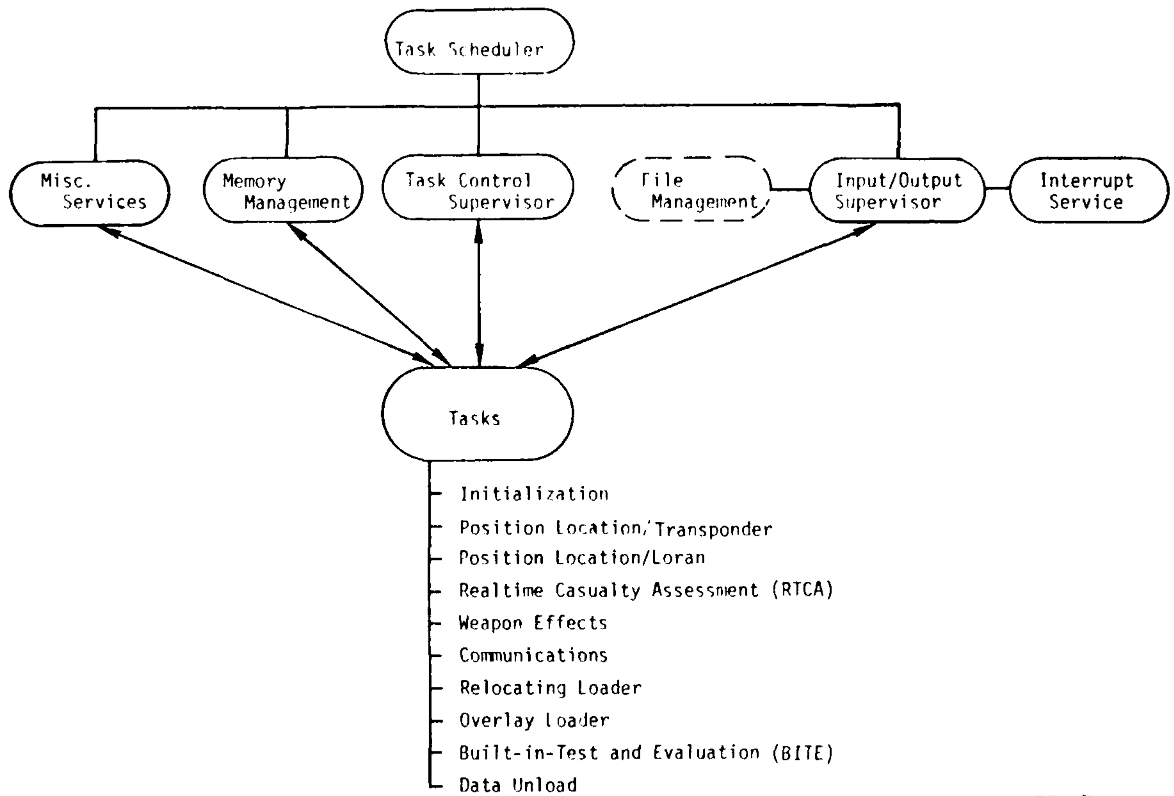


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Figure 30. Task communication paths. Tasks request service via supervisor calls.

have been developed at BDM previously, although modifications will be required to incorporate all of them. Monte Carlo techniques will be used to "force-fit" the algorithm to match existing AMSAA data over a statistically large sample. However, responsibility for the intimate details of the RTCA algorithm properly fall with the T&E contractor since test analysis is highly dependent on the precise details of the calculation.

3-2.1.2 Indirect Fire RTCA

Indirect fire weapons are fundamentally different from direct fire weapons and must be treated differently. Here the significant data are range to the projectile impact point, projectile type (hand grenade, etc.), and player shielding. While sufficient information is available to allow development of the computational aspects of this task, adequate simulators to provide input data have not yet been developed. Consequently, this task will remain in limbo pending further development of the simulators.

3-2.1.3 Position Location

Player position will be determined from either LORAN-C data or from transponder data. Baseline data is currently being generated to permit algorithm development to proceed.

3-2.1.4 RF Communications

The RF communications task interprets incoming RF messages from the master station, formulates a response, and transmits it.

3-3 DEVICE SERVICE ROUTINES (DSR)

Each hardware device in the player pack either supplies data to or requires data from the computer. Operating on the data, either to generate it or reduce it, is the function of various tasks. The actual transfer of data to/from the hardware is handled by the DSRs. The DSRs interface to ECS through a rigidly defined software protocol and perform all required interrupt processing and data transfers with the appropriate hardware. Each peripheral device requires a DSR. Peripherals and DSRs identified as required for TNF S^2 are shown in Figure 28.

SECTION IV
INSTRUMENTATION DEVELOPMENT PLAN

4-1 INTRODUCTION

The TNF S^2 Instrumentation will be the primary test and evaluation tool to be used in evaluating proposed improvements to the survivability and security of the Theater Nuclear Forces. The instrumentation will allow free-play, force-on-force testing with real time casualty assessment and facilitates the two-sided, free-flowing operational scenario necessary to realistically evaluate the effectiveness of the proposed improvements.

The development began in December, 1978 with BDM acting as the integrating contractor. The International Laser System, Orlando, Florida, was awarded a contract in March, 1979 to develop the weapons effects subsystem and VEGA Precision, Vienna, Virginia, was awarded a contract in September, 1979 to develop the RF transceiver subsystem. Coordination with several LORAN-C manufacturers took place throughout 1979 and evaluation of LORAN-C for use as a position location subsystem is continuing into December, 1979.

The basic design philosophy utilized during the engineering development phase is centered around a system that is to be modular, flexible, and easily expandable. The backbone or permanent position of the player pack consists of a microcomputer, power supply, and connectors to the various functional elements. Because the unit is computer controlled, with each player function acting as peripheral devices, it will be truly flexible and expandable.

A modular approach was utilized in the design of the player functional elements. This will allow hardware and software tasks to be performed in parallel under this proposed effort. The various functional elements are: (1) weapon simulation, (2) weapon detection, (3) data logging, (4) position location, (5) cueing, (6) direct ranging, (7) RF communications, and (8) hardware/software development system and the field O&M and quick-look systems.

4-2 DEVELOPMENT SCHEDULE AND TASKS

The Instrumentation Plan follows a primary or baseline approach, using LORAN-C for the initial position location system. This approach minimizes both schedule and cost risk factors and will provide for early field testing. The proposed effort also identified a parallel task to improve the position location accuracy, utilizing transponder techniques. The packaging concept is designed to provide for a direct replacement of the hardware units. Figure 31 illustrates the overall development schedule and Figure 32 shows the key program milestones for FY 1980.

Parallel development of the functional elements was accomplished during the first year's effort, with laboratory demonstrations performed during the fourth quarter of FY 1979 and the first and second quarter of FY 1980. Figure 33 illustrates the systems integration and design efforts to be performed.

A key factor in meeting the overall schedule was the timely acquisition of the Instrumentation Development System. This system was required at an early date to allow parallel efforts in both hardware and software development. It must, at a minimum, be configured exactly as the master station controller. To reduce recurring labor costs, it should be somewhat larger in terms of both main memory and disk capacity. The system was specified in September of 1978 and was never procurred for several reasons. The original system was configured to handle the additional task of data base management which is no longer required. Consequently it can be reduced in size and cost, nonetheless the requirement for it is still valid. Specification will be submitted to FCDNA in December, 1979 as to its final configuration.

4-3 RELATED EFFORTS FOR FUTURE PLANNING

There are several categories of instrumentation-related efforts which fall well beyond the scope of the current development program.

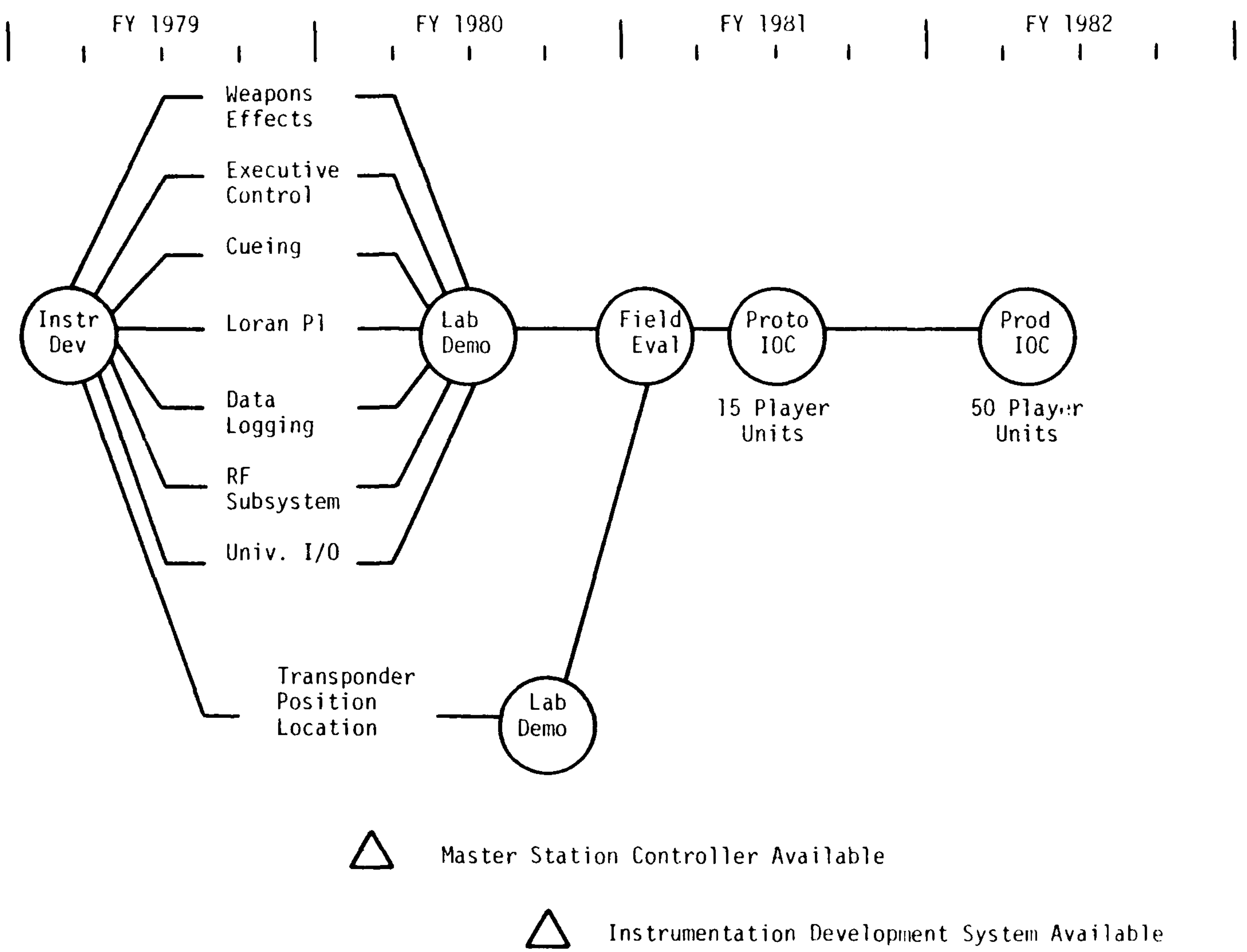

Figure 31. TNF S^2 instrumentation development master schedule.

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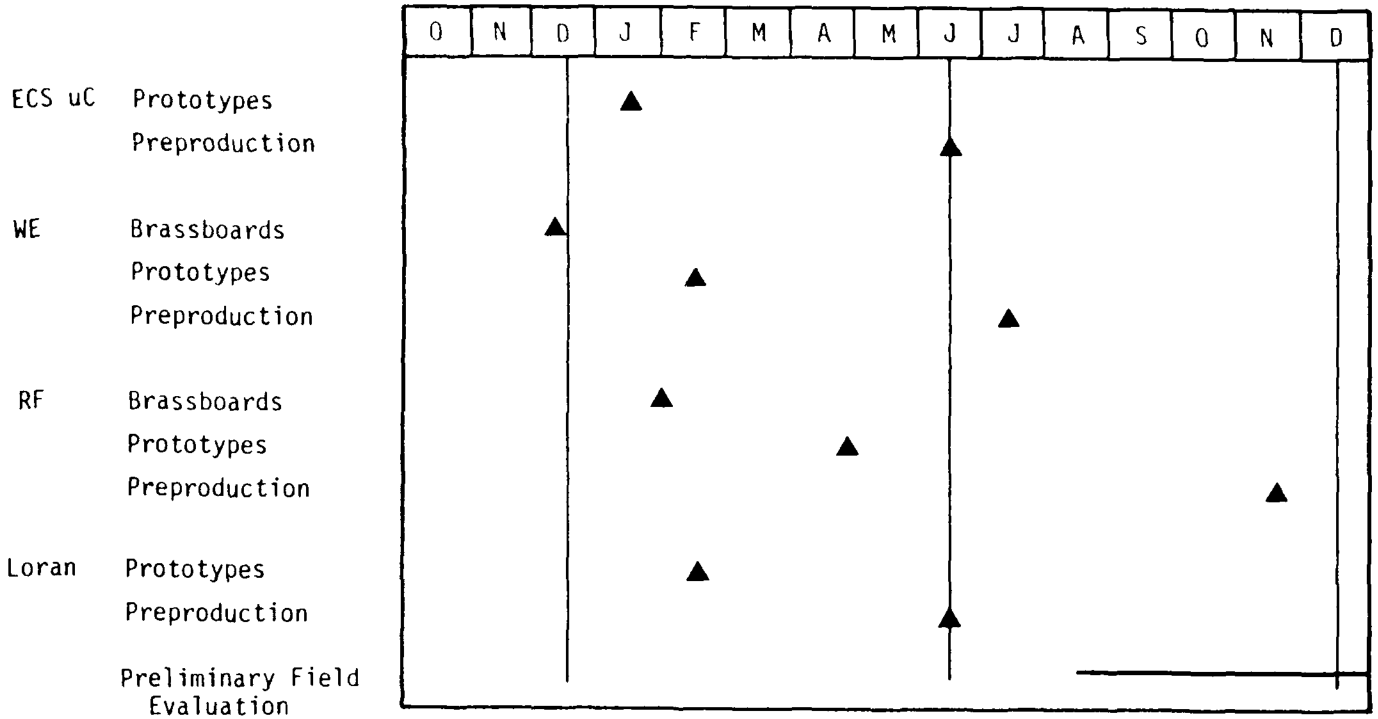

Figure 32. Key 1980 milestones.

These deal primarily with the long-term operations, maintenance, and the evolutionary aspects of the instrumentation and with test-specific requirements. To properly address these issues requires timely identification and funding of the required efforts. The following paragraphs illustrate those efforts that will be needed throughout the lifetime of the TNF S^2 program.

4-3.1 Continued Development

Continued development refers primarily to the long-term evolutionary aspects of the instrumentation. As new weapon systems are fielded, new hardware and/or software modules must be added to the player-pack to simulate these systems. Other additions such as flyout models, etc. will be required as conditions and equipment (both threat and friendly) evolve.

Also to be considered here is incorporation of advances in technology which would allow reductions in size, power, and weight of the manpack unit.

4-3.2 Issue-related Instrumentation

This category contains all the "unknowns." Special equipment required to gather unique types of data -- unknown now, to be identified as test planning proceeds. Such things as instrumented umpire equipment, closed-circuit TV, etc. fall into this category. Other developments include requirements for indirect fire simulators and smoke/flash/bang cueing devices. The question here is not IF such work will have to be done but WHEN.

4-3.3 Field Test Support

A certain level of engineering support will be required on a continuing basis for all tests to aid in set-up, deployment, data acquisition, maintenance, etc. This is particularly true when the instrumentation system is moved to a new site. The manpower requirements are partially dependent on the number of players to be involved in a test. Figure 33 shows estimates of these requirements.

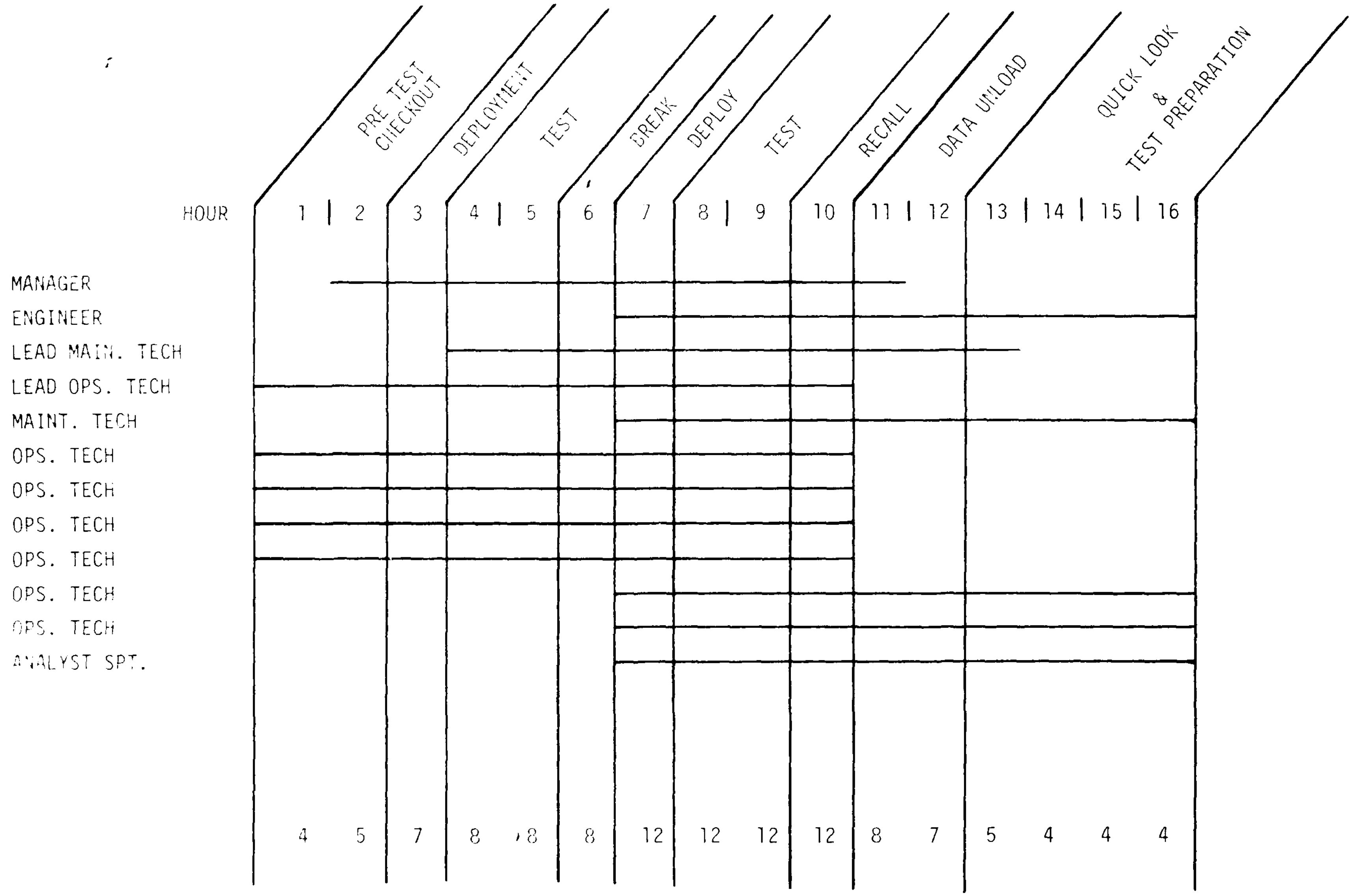

Figure 33. Typical instrumentation personnel utilization.

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4-4 DEPOT MAINTENANCE

The rationale behind the master station maintenance facility is to provide module-level fault detection capability for player pack modules and repair capability for low-level items such as connectors, batteries, etc. To provide board-level repair facilities in the master stations would drastically increase their cost. However, this approach presupposes that a depot maintenance facility with such capability exists. Thus, faulty equipment from several locations can be sent to a single facility for detailed fault analysis and repair. Such a facility should also be capable of performing remote maintenance (both hardware and software) on the mobile master station. The equipment required for a depot maintenance facility is precisely that required for initial instrumentation development, continued development, and issue-related instrumentation development as addressed in previous paragraphs. The Instrumentation Development System, described earlier, would provide the non-recurring core of such a facility. The only recurring costs would be those of staffing and operating it.

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APPENDIX A

GLOSSARY

A/D	-	Analog to Digital. An electronic means of converting a voltage continuous with respect to time into a number represented by a discrete set of voltage states. A continuous voltage is converted into a discrete digital word or number.
APU	-	Arithmetic Processing Unit. Provides floating point arithmetic, trigonometric functions, etc., on a single integrated circuit. Very high speed.
BIT	-	Unit of information equal to one binary decision, represented by a one or a zero.
BITE	-	Built-In Test and Evaluation. Self-test circuitry built into an electronics module which allows functional testing of the module during its operation.
BOOT	-	A software routine whose first few instructions are sufficient to cause the rest of the routine to be brought into the computer from an input device.
BUFFER	-	A sequence of locations in the computer's memory which are used for temporary storage of data. Used heavily when transferring data from the computer to an external device.
BYTE	-	8-bit packet of digital computer data.
CIU	-	Communications Interface Unit. A module in the TNF S^2 player pack which handles data conversion for both the laser weapon simulator and RF communications.
CMOS	-	Complementary Metal Oxide Semiconductor. Extremely low-power technology. Only a limited number of functional part types are available. Very slow operation compared to other technologies.

Appendix A. Glossary (Continued)

CODE	-	A sequence of computer instructions. Equivalent to "program."
CPU	-	Central Processing Unit. In a microcomputer this refers to the microprocessor component.
CRU	-	Communications Register Unit. A serial data link used by the 9900 family of computers to communicate with devices external to the CPU.
DMA	-	Direct Memory Access. The process of transferring information from one area of a computer memory to another without intervention by the CPU. It is orders of magnitude faster than CPU-controlled transfers.
DMAC	-	Direct Memory Access Controller. A single integrated circuit which, once initialized by the CPU, controls the DMA process.
DNA	-	Defense Nuclear Agency.
DSR	-	Device Service Routine. A software routine used to interface a device to the ECS software. An example of a DSR would be the software needed to transfer data from the computer to an external device such as the data logger.
DX10	-	Operating system for TI990 Minicomputer.
ECS	-	Executive Control System. The player pack microcomputer, including hardware and software, exclusive of the functional hardware modules.
EMF	-	Electromotive force or a voltage.
EPROM	-	Eraseable Programmable Read Only Memory.
FET	-	Field Effect Transistor. A voltage controlled switch.
FIFO	-	First-In-First-Out Memory. A single integrated circuit memory stack with a capacity of 4 to 64 bytes. Data is entered at a single point and retrieved from a single point in the order of entry.

Appendix A. Glossary (Continued)

GFE	-	Government Furnished Equipment.
GPS/ NAVSTAR	-	Global Positioning System. A position location system based on the use of synchronous satellites.
ID	-	Identification Code. Used to identify players, weapons, and weapon types.
IDF	-	Indirect Fire. Generic term referring to all military weapons except those used in a point-to-point mode, such as rifles. Examples: mortars, artillery, grenades, missles, etc. Usually with explosive rounds.
ILS	-	International Laser Systems, Orlando, Florida. Awarded contract by DNA for the Weapons Effects system.
I^2L	-	Integrated Injection Logic. The I^2L logic family can be easily interfaced to other logic families. I^2L is a new technology with high circuit density. It is current driven rather than voltage driven. Low power technology.
I/O	-	Input/Output. Refers to the generic data transfer process. Usually implies communications between a computer and its peripherals.
INTERRUPT	-	A signal from a device outside the microprocessor which tells the microprocessor that the device is requesting some sort of service.
LOS	-	Line of Sight. Refers to weapons which are usually sighted on the target (rifles, etc.).
LORAN	-	Instrumentation developed for the purpose of determining time-correlated fixed and dynamic position locations of players.
Low-Power Schottky	-	Same as Schottky except lower power and slightly slower in speed.

Appendix A. Glossary (Continued)

Main Frame Computer - The largest size computer. Usually several racks in size. Can support a wide variety of peripheral devices. Usually has a very powerful intruction set. Word lengths are usually greater than 32 bits with addressing capabilities of more than 100K bytes. Very fast with typically less than 1 microsecond average instruction execution time.

Micro-computer - A multi-chip computer which includes a microprocessor, system memory, and the necessary control circuitry. The system memory stores the programs and data necessary for the particular operation. The control circuitry interfaces the microprocessor to the other system components. Typically fits on one board.

Micro-Processor - A one-chip processing unit which contains an arithmetic/logic unit, temporary storage registers, and timing and control circuitry. Usually has a word length of 16 bits or less and an addressing capability of 65K bytes or less. Average instruction execution time is on the order of 1 to 10 microseconds.

Mini-Computer - An upgraded version of a microcomputer with an increase in speed, addressing capability, and the power of the instruction set. The physical size is considerably larger than that of a microcomputer -- typically a minicomputer is mounted in a rack. A minicomputer is usually able to communicate with a large number of peripheral devices including line printers, user terminals, and disk drives. Word length is 16 to 32 bits.

Appendix A. Glossary (Continued)

NMOS	-	N-channel Metal Oxide Semiconductor. NMOS is a logic family which is used primarily in memory applications. This logic family has a fairly high density while using relatively low amounts of power.
Operating System	-	The collection of software modules which control the allocation of the resources of the CPU and the external devices.
O&M	-	Operations and Maintenance.
PL	-	Position Location.
PROM	-	Programmable Read Only Memory. Memory which has the ability to be user programmed. Otherwise, same as ROM.
PSI	-	Programmable Systems Interface provides interrupts, I/O ports and interval timer for the 9900 System.
QCB	-	Queue Control Block. The block of control information used to store queue parameters. The information in a QCB includes pointers to the first and last object in the list and a count of the number of objects in the list.
QUEUE	-	A linked list of objects. The objects can be added to and deleted from the queue with relative ease.
RAM	-	Random Access Memory. A memory which can be read from or written to in approximately the same amount of time. Used to store data which must be changed.
Real-Time Clock	-	Hardware external to the microprocessor which interrupts the processor on a periodic basis. The real-time clock (RTC) can be used by the computer's operating system to implement such functions as time slicing and time of day (TOD).

Appendix A. Glossary (Continued)

Re-entrant Code - A string of computer instructions which is designed to be used by several calling programs at the same time. Production of re-entrant code is considerably more difficult than writing code without this property.

RF - Radio Frequency.

RFCIU - Radio Frequency Communications Interface Unit.

ROM - Read Only Memory. A memory that is used for storage of fixed programs or data. Retains its information when power is turned off. Contents cannot be altered. Contents set during manufacturing.

RTCA - Real-Time Casualty Assessment. A computer algorithm which determines the probability that an engaged player has been killed.

Schottky - A high-speed, high-power logic family. Easily interfaced to other logic families.

S^2 - Survivability and Security.

Sneak Path - A possibly unforeseen "path" between software modules. A sneak path can cause severe problems in the software.

SCB - Supervisor Call Block. A block of control information used when accessing a device service routine.

Subroutine- A section of code which is used frequently can be placed into a form such that any program which needs the service can "call" the subroutine. The use of subroutines can result in a considerable savings in memory requirements.

Supervisor Call - A mechanism by which a task can request a service that the operating system can provide. An example of such a service might be a request to transfer data between the computer and an external device.

Appendix A. Glossary (Concluded)

Task	-	A computer program which performs some computational function. An example of a task in the TNF S^2 player pack application would be the Real-Time Casualty Assessment (RTCA) Calculation.
Task Scheduler	-	The software module which determines which tasks in the system should become active and at which priority they should execute.
TI	-	Texas Instruments.
Time Slicing	-	The mechanism by which each active task in the system is given "slices" of a predetermined length of time to execute. Any given task may take several "time slices" to run to completion. The end of a slice is signified by an interrupt to the microprocessor at which time another task is allowed to become active and the first task is temporarily suspended. Allows tasks of equal importance to execute "concurrently."
TNF	-	Theater Nuclear Force.
TNF S^2	-	Theater Nuclear Force Survivability and Security.
TSB	-	Task Status Block. The block of control information used to store parameters about a particular task. The TSBs are linked together to form queues.
TTL	-	Transistor-Transistor Logic. A logic family characterized by its input/output features. Very commonly used.
USAFE	-	United States Air Force in Europe.
VMOS	-	Vertical Metal Oxide Semiconductor. VMOS is a new technology logic family similar to the NMOS logic family, except that VMOS is slightly faster but with lower density and lower power requirements.
WECIU	-	Weapon Effects Communication Interface Unit.

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